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MINING METHODS GEOLOGIC STRUCTURE STRATIGRAPHY OF THE MONONGAHELA RIVER BASIN, WEST VIRGINIA MARYLAND AND PENNSYLVANIA

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Geologic Structure
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of the
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West Virginia, Maryland and Pennsylvania

Monongahela River Mine Drainage Remedial Project

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A general descriptive framework of mining methods and features relative to the Monongahela River Basin is given. The regional geological structural framework within which the Basin lies, and the structural elements that comprise the structural characteristics of the Basin are described. The stratigraphic framework of the Basin is also developed.

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Mining Types - The purpose of this section is to develop the general descriptive framework of types of mining relative to the Monongahela River Basin and the objectives of the project. It will provide the basis for discussion of individual sub-basin areas so that undue repetitious description of mining methods and mine features will be avoided leaving only those unique features which reflect on the special problems of the sub-basin to be reviewed independently. The objective is: to describe mining methods and features in a form pertinent to the project; to provide a basis of common reference, regardless of background experience or approach of any person connected with the development of the project; and to increase the effectiveness of the results.

Underground methods - After first determining the characteristics of topography; drainage, depth, dip, thickness and extent of the coal; character of the immediate roof and bottom rock, character and thickness of the overburden in addition to other pertinent economic, real estate, legal and logistical problems: the proper entry and mining method are decided. The most favorable characteristics are identified and used to minimize drainage, rock fall and other pertinent problems. The decisions made do not always avoid creating conditions that may need remedial measures to control mine drainage in the future. Older mines received less if not little of this type of planning. Modern mines are developed, more than ever before, from detailed planning that includes some mine drainage pollution control measures.

When the coal outcrops or lies at depths less than about 800 feet the drift or slope entry is usually the optimum opening. Slopes are commonly accompanied by a vertical shaft for air ventilation and emergency use.[1] A drift opening enters the coal at the outcrop and mining forward into the coal is begun immediately. A slope enters a hillside in rock which is excavated downward to the coal. When the coal is reached, its extraction begins. When the strength of the rock, depth of the coal or other conditions are unfavorable a slope may be used to approach a seam that might otherwise have been entered by the drift-type entry. When coal occurs at depths greater than approximately 800 feet, the shaft entry is used. A shaft is a vertical excavation for the entry and exit of supplies and men, ventilation, and the removal of coal. One or more shafts may be excavated through rock to the coal seam. Mining of the coal proceeds laterally outward from the bottom of the shaft.

Once the coal has been entered, two or more headings are driven to enlarge the access and develop the working area or faces into the coal seam. From these main headings lateral mine development can be classified, largely on the effect upon the main rock mass overlying the mining.[2]

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[1]Coal Age Mining Guidebook, Coal Age, August 1966, pp. 177-284.

[2]Weir, J.P. (1966) Methods of Mining Bedded Deposits, Society of Mining Engineers Reprint No. 66AM51.

1. Room and pillar with partial extraction - In this method, cross cuts are developed at regular intervals between headings. The result is a series of solid blocks of nearly square orm rectangular coal bounded by passageways in two directions. The pillars are large enough so that the weight of the overlying strata is supported, and downward movement of the roof is prevented or occurs but slightly.
2. Room and pillars with pillars extracted - Pillars are formed as described during so called first mining. Once the area has been fully exploited because of limits of leases, changes in coal, economics of the mining plan or other reasons, so called retreat or second mining removes the pillars as the forward areas are regressively abandoned. All effective resistance to downward movement of the overlying rock mass is eliminated. Under ideal conditions, a nearly vertical shear develops and subsidence occurs with little if any extension beyond the subsided area.[3]
3. Room and pillar with combination pillar extraction - The pillars formed in first or second mining are too small or not numerous enough to support the overlying rock mass. Deformation of the pillars develops and bending and fracturing of the roof occurs.

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[3]Tilton, James G. (1966) The Effect of Subsidence on Pipelines, American Institute of Mining, Metallurgical and Petroleum Engineers.

4. Longwall mining with complete extraction - The main headings are laid out so that a long face of a large block of coal is accessible to the cutting action of a plow or shearer combination cutting and loading machine. The mining action is continuous back and forth across the face. The roof is supported on the mining side by the coal that is in place and not yet mined. The area of the immediate past mining is supported by mechanical roof supports, the most modern of which are self-advancing. The main roof is systematically lowered to a new position on the floor of the mine. This differs from the room and pillar caving in that ideally the roof over the coal breaks to a height of 3 to 4 times the coal thickness, swells in volume and forms a cushion to receive the still intact but downward bending rock mass. The surface is lowered uniformly and surface cracking, lateral movements and subsidence damage is minimized.

Special openings - Adequate ventilation must be provided to remove explosive gases, dust, and poisonous fumes, through openings developed for the installation of air ducts and fans. Additional openings may be provided to insure access and egress for the health and safety of the men, or other logistical problems.

Exits may be necessary for the removal of excessive mine waters collected in the workings as mining cuts through ground water channels. These openings may be the extension of a working area opening to the surface from a low gathering point in the mine, or it may be an excavation driven specifically for drainage. Shafts or bore holes may have been provided for the specific purpose of removing mine waters.

Water handling - If water is not excessive it will be accumulated in the lowest abandoned area of the mine while mining proceeds to higher areas. Excessive water is removed from the mine by gravity drainage or pumping to the surface. Modern mining techniques consider the possibilities of preventing as much water as possible from entering the mine. That which does enter is removed as quickly as feasible. Contamination of mine waters is controlled in some modern mining by reducing the amount of acid-producing material the mine water may contact and shortening the contact time. Contaminated waters are discharged over aeration ladders to reduce the amount of contaminants. Settling ponds are used to hold water while part of its load is chemically and physically modified and precipitated to the pond bottoms. Pumping schedules are used to effectively control the discharge to as small a load as possible at any one time. Special chemical treatment techniques are used in conjunction with aeration and ponding to change the composition of the water before it is released. Where mining operations have storage facilities and preparation plants to upgrade coal quality; the total operation system will include water control techniques to reduce vagrant water entry, recycle and treat used water.

Surface methods - After exploring the coal and rock characteristics and matters related to an economic coal operation, it may be decided that all or part of the coal should be removed by surface excavation methods. The first operational step is to remove the forest or other growth, soil and subsoil from the area to be mined. The strata occurring above the coal is removed next. Where

appropriate conditions are found perhaps the entire overlying rock interval may be removed by bulldozer or scraper or in combination. Where strata are hard and resistant they may have to be broken by ripping the strata with mechanical or hydraulic rippers. Drilling and blasting are required for the harder strata. Shovels commonly are used to remove the bulk of the overburden after the surface material only is removed by scraping. Where steep and rapidly rising slopes prevail and the underlying coals are to be removed, the dragline may be the best machine. Comprised of a bucket affixed to a long boom and lowered and raised by a cable, it can span great depths, heights and distances where other machinery is ineffective or uneconomical. The overburden may be removed in one or more stages or levels after fragmentation by drilling and blasting. Once the economic vertical height of the overburden has been reached, relative to the thickness and quality of the coal present, then an auxiliary surface method penetrating the coal beneath overburden may be feasible. The horizontal auger is the machine used for this task. After the coal exposed by stripping has been lifted with highlifts or shovels, loaded on trucks or conveyors and hauled away, the auger is placed in the floor of the pit. This horizontally oriented screw-shaped cutting device is placed against the coal seam face and rotated into the coal. The broken coal moves helically along the curved grooves of the screw outward to the entry onto a conveyor, into a truck or haulage conveyor, and then is transported away from the mine.

During mining, surface water is diverted away from the pit to avoid excessively wet conditions. Ground water enters the operation when its underground channelways are intersected by mining. Occasionally underground workings are intercepted and sometimes large volumes of underground mine water have to be managed.

Upon completion of the coal removal the pit may have been abandoned or filled to some degree with the broken overburden. Modern surface mining methods ram overburden material into the auger holes and intersected drifts. Any sulfuritic material that is detrimental to the quality of water is placed in the bottom of the pit, then covered with broken overburden or material from the top of the unmined area. The last remaining face or highwall of the mine is reduced in vertical height or completely buried when the backfilling is complete. If the overburden from the first cut has not been stacked on the outer edge of the cut, and not cast outward on to the slope below the coal, a minimum of area is disturbed. Special conditions of soil cover over the bed rock or the nature of the slope or drainage patterns may cause the cast material to slide downward in an undesirable manner. The final water diversion scheme of some modern mining practices helps to avoid this consequence, as well as control the amount of water and time of its contact with stripped and broken overburden or spoil areas. Subsidence of the highwall is also reduced by the control of surface water flow and its eroding effects away from the highwall as well as the backfilling procedures and the lateral support they can provide.

Relation to Abatement and Remedial Measures - When mining first began in the days of the pioneers, the operations were not large or well organized. Coal was dug by hand in so called farm, country bank, or dog hole mines and the consequential effects were small. As industrialization developed, mines became larger and some planning was begun. With the introduction of machines, planning became very important to the success of the resulting larger and faster moving operations. With the growth of population and industry and the size of the mining industry serving them the effects of the mining upon the surrounding environment became increasingly obvious and disturbing. The lack of any organization of the work to prevent subsidence, water quality, or esthetic damages led to a build-up of conditions that will be deleterious as long as they are allowed to remain, at least as they have been left. The introduction of techniques to minimize the repetitious growth of these conditions has had a limited beneficial effect. Since it is likely that more coal will be mined in the future than in the past, it is important that abatement and control techniques become increasingly more common. As to the scars of the past it is not likely that more than a few of the total underground and surface mines that have been created will become compatible naturally with the surrounding environment within a period of time acceptable to society. The greater bulk of the operations have left openings, subsided areas, coal refuse piles, and acid mine water drainages that are intolerable to the surrounding environment. With these sites it will be necessary to seal openings and boreholes, regrade spoils, cover sulfuritic refuse, divert water, treat water

and perhaps extinguish some refuse bank fires and burning abandoned underground mines or coal outcrops to effect an improvement on the quality of water and related desirable environmental characteristics.

General reference: Peele, Robert and Church, John A. (1941), Mining Engineers Handbook, Vol. 1, John Wiley and Sons, Inc.

Geology

Structure - The purpose of this section is to define the regional structural framework within which the Monongahela River Basin lies, and the structural elements which are of greatest importance that comprise the structural characteristics of the basin. The objective is to provide a background reference for sub-basin description. The reason for referring to geological structure of the basin proper and sub-basins is that it is one of the factors that have guided erosion and deposition of sediments throughout time to the present. Therefore, the rock strata that remain and their orientation can be better understood relative to the presence of coals, the patterns of mining, the prospects of further use of remaining reserves, the surface and subsurface drainage patterns, the remedial and abatement measures needed presently and in the future, and the consequences of those measures as they may be influenced by the controlling structural features. More effective abatement and remedial measures could be the result.

Regional Structural Relations - The Monongahela River basin lies in the approximate center of a structural downwarping of the earth's crust known as the Appalachian basin. It extends from southern Canada to central Alabama and Mississippi roughly parallel with the Atlantic coast. Its breadth ranges from eastern New York, Pennsylvania, western New Jersey, Maryland, Virginia, and Georgia on the east to western Ohio, central Kentucky and Tennessee on the west. The structural downwarping has been filled with up to 60,000 feet of a great variety of sediments that have

been compacted and lithified into rock strata. Periodic distortion of the sediments and strata have created a series of convolutions and disruptions of the rock collectively known as structures. The result has been a series of subsidiary low or basin areas bounded by higher mounded areas. Within these smaller basin areas, structures of even lesser scale have resulted in further irregularity of the basin form. Increasingly closer inspection will result in the recognition of smaller and smaller structural molding or distortion of the rock; and if it were desirable such features could be identified and related to individual grains comprising the rock strata. Erosion by the various processes of weathering, transportation and deposition relating to structures and rock types has modified the surface of the area into the distinct and varied land forms present today. Grouping of similar land forms are possible into a number of separate areas known as physiographic provinces. They range from high plateaus to low valleys and vary from rough, steep slopes to nearly flat undulating surfaces.

Local framework - Although it lies within the Appalachian structural basin, the Monongahela River basin is further subdivided into smaller structural depressions with intervening mounds. Flexuring of the strata has developed a series of linear highs and lows that trend principally northeast to southwest. They are most dominant and pronounced in vertical height in the eastern part of the basin. Each successive structure to the west lies somewhat lower vertically in the structural basin and is less pronounced. The surface features are grouped into the Appalachian Plateau Physiographic Province. However, the aforementioned structural

characteristics and related rock types have caused the erosion of the eastern part of the basin to produce topography that has linearity approximately parallel to the northeast-southwest structural warping trend, which becomes decreasingly obvious and eventually indistinct westward. The difference between west and east are the basis for a physiographic subdivision terminology which refers to the east as the Allegheny Mountain Section and the west as the Kanawha Section. The separating boundary of the sections lies slightly west of a trend roughly parallel with Tygart Creek.

Structural Elements - Anticline - Just as the Appalachian Basin is bounded by high areas around its perimeter, it in turn is comprised of a series of smaller structural basins bounded by intervening highs. The basins of downward flexured strata have perimeters of upward flexured strata called anticlines. These upfolded conformations are composed of a top or crest with legs or flanks extending or dipping downward towards the depressed areas bordering the flanks. The crest can be broadly curved, flattened or angular. The legs can dip downward at steep or gentle slopes. When each flank dips uniformly with,but in the opposite direction from its mate, then the anticline is defined as symmetrical. When the degree of dips vary, then asymmetrical is the proper definition.

If a line is drawn along the crest or the crestal area of any folded bed comprising the anticline, then this line is the axis and defines the area where the dip of the strata extends in opposite directions. If all axes of each bed of strata are connected by an imaginary plane, the plane is the axial plane and divides the fold roughly in equal parts. Where the projection of the axial plane

intersects the topography and appears as a line on a geologic map, it marks the approximate center of the uppermost surface of the anticline and is called the axial trace. Commonly it is referred to as the axis of the fold, but axes are drawn through individual beds of the fold and the crestal area of each bed within the fold may not lie directly and vertically in line with other axes of beds in the same fold. Therefore, this use of the term is misleading, insofar as a correct understanding of the location of the surface expression of a fold is related to its subsurface position. Although folds are not greatly askew or assymmetrical in the vertical depth of study within the Monongahela River basin, this is not as broad and serious a problem as it might be, but nevertheless it may be important in some portions of the basin.

Since folds do not always occur in perfectly straight and continuous lines but undulate and terminate, then the axial plane will be bent and the axial trace will be a curved line with terminations on the map. Where the axial trace bends on the map the generally downward dipping strata will have a warped rolling orientation rather than a smooth flat sloping flank. Where the axial trace terminates upon the map, this marks the area on the ground where the dipping strata of the flanks wrap around and across the axis to meet and close the end of the fold in a form called a structural nose. If the nose is examined, the dip of the strata can actually be observed to bend from dipping in one direction on one flank to a position perpendicular to the flanks and finally to dipping in the opposite direction on the parallel flank. Where a fold does completely close at the end

the axis curves downward or plunges to extinction. Where the plunge does not reach extinction but rises again in response to the form of increased upward development of the fold, then a depression or saddle is formed along the axis or axial trace. The high area between two plunging zones along the axial trace may be distinct enough to be called a dome. These features of an anticline are related to distinct orientation features of the rock strata, their pattern of exposure or outcrop and presentation on the geologic map, the presence of coals and coal mines, the surface and subsurface drainage characteristics and ultimately the design and impact of remedial measures.

The orientation of the strata will be a dip downward, away from and parallel with the axis along the flanks. At the noses and saddles the dip of the strata will migrate towards the axis.

Where erosion has excavated or breached the surface into the core of the anticlines, on a geologic map the strata will appear as parallel bands along the flanks, being broadest along the higher portions of the anticline, and narrower at the saddles and disappearing at the noses.

Where the heart of an anticline is exposed by erosion the oldest strata will appear closest to the axes, and if erosion has penetrated deep enough, all coal-bearing strata may be removed. If so,it will indicate an anticline of major magnitude. A lesser anticline will not be the site of such deep erosion; but older coals may be found at the crests and younger coals lower on the flanks, in the saddle and nose areas.

Surface drainage will tend to conform to the anticlinal

uplift and major drainage will favor the border land. An exception may occur if the core area of the anticline is breached to a highly erosive rock type that favors the development of a major stream course. Where the anticlines are linear, the drainage pattern will be boxlike or trellitic with tributaries flowing down the flanks perpendicular to the axes then merging with large streams flowing parallel with the axes. Where the linearity is not pronounced or massive rocky types dominate the surface, then a branchlike or dendritic pattern will predominate.

Subsurface water penetrating the strata and becoming ground water will tend to follow the strata downward in their dip direction until it eventually escapes to the surface along the sides of hills or in valley stream floors.

Design of remedial measures will be more effective when recognizing these anticlinal influences because it will assist better determination of: 1) the most advantageous areas for emplacement of wet and dry structures; 2) the optimum areas for impoundments; 3) the probable course of underground water movement; 4) the possible overflow of underground pools that may be created; 5) the strength of structures relative to structural influence upon the strength of the strata; 6) the probable hydraulic heads and pressure that will be built up as water collects up the dip of the strata behind mine seals; 7) the effect of remedial measures relative to the consequences of water diversion; 8) the mixing of mine waters from different sources; 9) the current and future mining at locations up and down dip or plunge and in higher or lower coal seams; and 10) the ultimate amount of coal reserves that may be affected.

Syncline - The second major structural element is the downward flexured structural basins parallel to the adjacent anticlines. These depressed areas are known as synclines. They are the mirror image of anticlines and their dominant character and effect is inward and toward the structure in contrast to the anticlinal influence of outward and away from the structure. The central area of the syncline is the trough with legs or flanks extending or rising upward towards the elevated areas bordering the flanks. The trough can be broadly curved, flattened or angular. The flanks can vary and symmetrical or asymmetrical form is possible. Axes can be drawn to mark the area where the dip of the strata rises in opposite directions and axial planes connecting them roughly bisect the fold. The plane can be projected to the surface as an axial trace appearing as a line on a geologic map and having a similar relation to synclinal folding position at depth as described for anticlines. Similarly the askewness or asymmetry in the study area is of the same magnitude and extent as anticlines, and of limited importance. The undulating and terminating aspects also apply to synclines but with the opposite effect upon the orientation of the strata and the geologic map description of the strata. Where the axial trace bends on the map the generally rising strata will have a warped rolling orientation rather than a smooth flat sloping flank. Where the axial trace terminates upon the map, it marks the area where the rising strata of the flanks wrap around and across the axis to meet and close the end of the trough. If the closure is examined the rise of the strata can actually be observed to bend from rising in one direction on one flank to a

position perpendicular to the flanks and finally to rising in the opposite direction on the parallel flank. Where a trough does completely close at the end the axis curves away from the plunge direction which is downward towards the trough and upward towards extinction. Where the curve upward does not reach extinction, but descends again in response to the form of increased downward development of the trough, then a platform is formed along the axis or axial trace. The low area or plunge center between two platform areas along the axial trace may be distinct enough to cause the downwarped syncline to be recognized as a "canoe-shaped" basin.

These synclinal features have a comparable relation to strata orientation, outcrop, maps, coal, mining, drainage and remedial measures as do anticlinal features.

The strata will rise upward, away from and parallel with the axis along the flanks, but they will converge towards the trough ends and platforms.

At the outcrop or on the map of those areas where erosion has excavated the surface into the heart area of the syncline, the strata will appear as parallel bands along the flanks, being broadest along the lower portions of the syncline and narrower at the platforms and will disappear at the trough ends.

The youngest strata will appear closest to the axes and if erosion has penetrated deep enough, older coals or pre-coal-bearing strata could appear in the heart area. If so, it will indicate a syncline of minor magnitude merging with major anticlinal structures on its flanks. The dominant occurrence is younger coals in the central synclinal areas and older coals higher on the flanks, on the platforms

and trough ends. Surface drainage will tend to conform to the synclinal downwarp, and major drainage will favor the axial area. An exception may occur if the core area of the syncline is comprised of a highly erosion-resistant rock type that causes lateral shift of stream bed development. Boxlike trellitic drainage will predominate where the synclines are prominent and linear but branchlike or dendritic patterns predominate where the strata approach horizontal positions.

Ground water will tend to follow the strata downward in their dip direction towards the center of the trough until it escapes to the surface along hillsides or valley floors.

Remedial measures based upon the influence of synclines will recognize these areas as the probable focus of water accumulation requiring: 1) the majority of wet control remedial measures; 2) impoundments; and 3) designs to cope with the greatest hydraulic head pressures against seals. Synclinal areas have favored the preservation of younger coal-bearing measures and the majority of past and future mining activity and problems. Consequently, the future effectiveness of remedial measures and perhaps the future of mining are most strongly interrelated in the synclinal areas.

Other structures - Where the forces, acting upon the Appalachian basin portion of the crust of the earth and the immediate area of the Monongahela River basin, were not dissipated into anticlines and synclines of major magnitude, the strata reacted to relieve the pressure in other forms. The folding process has occurred on all scales, small folds a few dozen yards across are common and others small enough to hold in one's hand are known. The latter are relatively unimportant but the former causes problems in mining and

could cause some problems in controlling large areas of drainage from escaping from one underground area to another.

If the rocks could not fold they broke and the walls of the breaks may have separated or moved past each other. Smaller breaks and separations are fractures or joints. When occurring within the coal seams they are often called cleats and butts. They occur in at least two and sometimes more directions. They may be very closely spaced or occur at intervals of several feet from each other in massive heavy rock types. Faults may occur as slight dislocations or movements of several dozens of feet along separations of the strata. Since the strength of the rock and its ability to hold or pass water is determined in part by the presence and character of these structural elements, they should be closely examined and be carefully considered in the design of remedial measures.

Monongahela River Basin Structure - The portion of the structural basin underlying the Monongahela River basin is highest structurally on the southeast, east and northeast margins and lowest on the southwest, west, and northwest margins. The heart area is highest structurally in the northern half and lowest in the southern half. Because of this structural basin configuration the anticlinal cores are higher in the higher regions, and older strata are present there. In the lower areas the reverse is true. From east to west and from north to south the structures as expressed on the surface become less pronounced in height and are low nearly flat rolls in the lowest areas of the basin. The synclines are correspondingly higher and contain less of the younger coal-bearing strata in the higher basin areas and more of them in the lower areas.

Depending on the criteria chosen to group partially discontinuous axes together and the scale of size of anticlines and synclines, then for general analytical purposes, the basin can be considered to contain about 51 structural axes, each of about four miles or more in length. Many minor structures would not be included in this figure, especially in northeastern Tucker County where pre-Pennsylvanian, non-coal-bearing shales contain many small folds. Many folds of smaller magnitude of course are present throughout the basin as well as faults and joints which will be important locally relative to mining and remedial measures. The axes are fairly evenly distributed throughout the basin.

A section drawn transversely across the southern part of the basin will show about 7 anticlines and 8 synclines, and a similar analysis across the northern part of the basin will show 9 anticlines and 9 synclines. From this cross-section analysis it will be evident that only two anticlines persist across the principal length of the basin: The Deer Park across the eastern edge and the Chestnut Ridge across the approximate center. In addition, the Blackwater crosses the basin along the southeasternmost corner and the Amity crosses the northwesternmost corner. Another analytical facet is that along the northern cross-section four anticlines can be considered major in that they have resulted in the exposure of pre-Pennsylvanian, non-coal-bearing rocks in their heart area. From east to west they are: Deer Park, Negro Mountain, Laurel Hill and Chestnut Ridge. Across the southern cross-section these axes are not identifiable or are represented by lesser anticlines except for the Deer Park. This reflects the overall structural basin slope

to the south. In addition to the Deer Park with its non-coal bearing heart area, the Black Water and Horton Anticlines appear to the east also with their heart areas exposed to those older strata. All other anticlines are of lesser importance in that coals will remain in the heart area although the more dominant ones contain only the lowest older seams.

Similar cross-section analysis of the synclines indicates that none of the synclines persist across the basin comparable to the anticlines. The most dominant from east to west in the north are these: Berlin, Lower Youghiogheny, Lexington, Ligonier, Connellsville-Uniontown, Lambert, Waynesburg and Ninevah. Across the southern cross-section the major synclines are from east to west: Job, North Potomac-Georges Creek, Belington, Ligonier, Grassland, Shintown and Robinson. Of these only the Ligonier is clearly traceable as continuous from the northern section, although it does not persist across the southern edge of the basin. The Robinson syncline, however, does appear to have an intimate structural affinity to the Waynesburg Syncline. The easternmost Job Syncline lies on the outer upper part of the higher area beneath the Monongahela River Basin and being structurally high has resulted in the erosion of all coalbearing strata. The adjacent North Potomac-Georges Creek Syncline to the west contains only the lowest coal group. The slope of the structural basin westward being greater than the flattening of the syncline has caused increasing greater amounts of overlying coal groups to be preserved in the Ligonier Syncline.

This trend in preservation of younger coals is progressively so westward.

The outcrops forming the surface of the Monongahela River Basin reflect the structural elements present. The predominance of well developed dominant anticlines in the east has caused the oldest non-coal-bearing strata and the older coals to be present in the eastern edge of the basin. Successively younger overlying coal-bearing groups partially lap upon each other westward to the westernmost part of the basin where the highest and youngest strata form the surface. Since many of these structurally high and low areas were probably present during the time sediments were being deposited, some of the rock types may be in part accountable to them.

The geologic map reflects a structure with outcrop patterns that are long linear bands in the easternpart of the basin which merge at the place representing where major anticlines and synclines plunge downward. The result is an obvious "zig-zag" pattern on the map. Although this is most obvious when individual traceable beds are examined, groups of strata also demonstrate it. As the structures decrease in intensity or flatten westward, the "zig-zag" pattern is replaced by less distinct but longer linear parallel bands of outcrop. The graphic effect of a partially onlapping shingle pattern predominates, with the westernmost linear bands being the youngest.

Coals, of course, are most abundant in the structurally low western portion where they have been depressed relative to erosion and preserved. The influence of anticlines warping the area with increasing intensity eastward and up the general major basin slope ultimately results in the absence of coals in the eastern margins. Those coals on the surface in the west are thus decreasingly present eastward.

Those coals present on the east are increasingly present and deeper beneath the surface westward. To a lesser degree a similar relationship is found from north to south. Of course, the lack of continuity of the presence of, or thickness of, coals will modify locally this general descriptive statement.

Mining will be found related to structure in that where structure relative to erosion has made coal most easily accessible, that is the point where mining has commenced. Thus the older mining and the least remaining reserves are closely associated with structurally high areas relative to synclinal basin configuration where coals have been preserved and outcrop at the surface. Mining will have utilized the structure of the strata where possible by entering, draining or pumping from structurally low areas and keeping the active operations in the structurally high areas to take advantage of the downgrade for natural drainage, haulage and ventilation purposes. Newer and larger mines will tend to predominate in the structurally lower part of the basin where drifts or slopes from the outcrop area have penetrated to depth, or shafts have been excavated from the surface downward to the coal seam. Pumping of course will be the major method of mine water discharge in those instances. Where suitable quality coal outcrops with much of the overlying strata removed by erosion, then surface mining methods are prevalent. The oldest worked areas were located in the best quality most easily reached coal. Surface mining excavation by hand, machine, and horizontal auger methods will be observed there. Auger mining will be most abundant where the structure is suitably, uniformly and moderately sloping to physically favor economic recovery. Thus understanding the structure may suggest much in the probable relationship of mines, drainage and a strategy

for developing or remedying the effects of mining in an area.

Although the structural trend is northeast-southwest in the basin the overall topographic slope is towards the north being transverse to the structural trend. Therefore, the surface drainage is ultimately to the north. Nearly all of the stream patterns are influenced by the structural trend and very much so on a local scale. This is most obvious in the east where the boxlike trellitic pattern predominates.

Ground water can be expected to favor the dip of the strata even where fractures in the rock are the chief channels of subsurface movement. Of course where mining has occurred the drainage will favor the slope of the mine floor. Generally this floor follows the top of the strata meeting the bottom of the coal as the support for the seam, and thus is nearly coincident with the structural orientation of the strata. Generally the principal tributaries favor the synclinal areas and thus the ground water flow that feeds them. Therefore, structure becomes an analytical and predictive tool for these flow patterns.

Ultimately understanding of the structure of the area will assist in developing a plan and strategy for remedial measures and estimating their effectiveness and long range effect. Remedies should utilize structure for mine water mixing, intermine water traffic control, strength and design of structures and protection of remaining coal reserves and any present or future activity that may be affected by them. The planning of future mining should use structural interpretation to its maximum advantage for mine drainage abatement and control designs.

Geology

Stratigraphy - The purpose of this section is to develop the general stratigraphic framework of the Monongahela River Basin relative to the objectives of the project. It provides the basis for discussion of individual sub-basin areas so that only the pertinent stratigraphic details relative to the proper understanding of the sub-basin need be reviewed independently. The objective is to reveal the stratigraphic features that will benefit a better remedial program by indicating the character of the strata, their distribution and variation. Understanding these features even in gross aspect will aid better correlation between coal seams and mines, the character of the surface and ground water related to rock types and because of this, more effective and safer remedial designs.

Major Stratigraphic framework - The Appalachian geosynclinal downwarped area described under geologic structure of the basin was a filling basin as it was depressing. Sediments were derived principally from the east although some deposits originated from the west also. Only in the later stages of deposition were sediment source areas in the north important. The rate of subsidence was greatest in the east and therefore the thickest and predominantly coarser sediments are present there. Sediment filling was nearly always in a shallow sea environment; but occasionally the balance between subsidence and filling was exceeded by the rate of deposition causing sediments to accumulate above sea level. These sediments were subsequently compacted and lithified to rock strata as they are known today. Observed vertical changes in the rock types reveal the sediments were different, suggesting that at different

times at the point of observation the environment of deposition was alternately inundated to various depths or exposed to the surface. Lateral changes in rock types suggest that different parts of the basin were different kinds of depositional sites at any one time. Rock types known to exist in one area but not in another suggest that similar sediments were not deposited because of disimilar environment at those spots, resulting in no deposition of sediments of that type. Or perhaps the comparable observed stratigraphic points, during subsequent periods of time, had vastly different erosion experiences resulting in the destruction of the once present comparable strata. Thus throughout large areas of the basin similar depositional environments collected similar sediments at the same time, but they were not necessarily contiguous. These environments shifted location and perhaps returned somewhat modified in deposit accumulation characteristics. Therefore a great horizontal and vertical variation must be expected in rock types. Further, if it were desirable to do so, increasingly finer inspection of smaller and smaller rock samples of the basin could reveal ultimately the differences between small groupings of rock fragments or between individual grains, which would reflect the conditions of the micro environment that determined which grains of what character were to rest at that point. Proceeding in the opposite analytical direction towards the macro scale of depositional environmental change, an examination of the magnitude of one sediment type over the other will indicate the progressive predominance of transitional delta type deposits over submerged marine type deposits, followed by typical terrestrial non submerged or sub-aerial types of deposits and eventually by uplift of the basin to where erosion predominates

over deposition and the complete exposure of the basin as it is known today. This surface is underlain with something less than its estimated original 60,000 feet of original sediments, perhaps 40,000 feet.

Local framework - The area of study which lies in the approximate center of the Appalachian depositional basin as we know it today contains representation of all of the rock types and ages deposited in the basin. The upper vertical limit of the basin, which is exposed in the study area, includes some pre-Pennsylvanian non-coal-bearing strata that were deposited in dominantly marine environments. But they are relatively unimportant to the project objectives except that they are areas of no coal, therefore no mining, and thus the source of reasonably good quality water unaffected by mine drainage with an overall beneficial effect upon water quality leaving the basin. All other strata are coal-bearing, however. They are the products of a mixture of sea (marine); transitional including beach (littoral); small bay or inlet (lagoonal); river mouth (delta); lake (lacustrine); swamp (paludal); stream (alluvial); and to a minor degree desert environments. The swamp environment, from which the coal seams originate, and the closely related horizontal environments (largely contemporaneous) and the vertical environments close above and below are of the most importance because within these environments the rock types are derived that are critical to an accurate understanding of the correlation, and geometry of the rock layers, the bearing strength of strata underlying the coal, the arching strenght of strata overlying the coal, the quality of the coal, and the composition of the strata relative to the quality of ground water, surface water and mine drainage that contacts those rock layers.

Stratigraphic Elements - Some of the basic elements of a stratigraphic basin will be reviewed, as a basis for better understanding the stratigraphy of the Monongahela River Basin and ultimately more effective design of remedial and future abatement and control measures.

A sedimentary basin is a depression to which eroded rock and soil fragments along with dissolved minerals and plant and animal remains are transported and deposited to be further altered and rearranged within the basin and eventually if not immediately buried, perhaps permanently, to become compacted and lithified rock if the process is completed.

The sedimentary environment determines the properties of the sediment and the rock derived therefrom because of its characteristic chemical, biological, and physical properties.

The environment is defined by analyzing evidence that will reveal its materials, boundary conditions, energy and biological complex. The texture and composition of the transported or deposited load and whether it is deposited in water, air or something else comprise the environmental materials. Such factors as the geometry of the environment in terms of depth of water, shape of the surface and configuration of the basin determines the boundary conditions.

Energy analysis is concerned with evidence that will reveal such things as wave or wind action, currents or slumps, and slides caused by gravity or other forces.

Since living organisms can produce significant effects on depositional environments, such as plants forming coal, it is important to understand the biological complex of an environment,

and the direction it may give as to nearby environments and the resultant character of the resulting strata as well. Further, use of the biological complex could aid correlation of strata and improve remedial measure design.

Recognizing that depositional environments will be numerous and variable throughout the vertical and horizontal rock strata record is the first step. Secondly, it is important to realize that numerous rock bodies, differing slightly or greatly in composition and form but related in time and space, will occur. For example, it is risky to consider a coal at a particular place as belonging to a known group that is characteristically an acid producing seam on the basis of the mine drainage water quality alone. The environmental factors prevailing during and after deposition at that local stratigraphic spot could account for those characteristics although the seam prevailingly is not highly sulfuritic. Or perhaps locally an extremely pyritiferous (iron sulfide) rich black shale or sandstone lying close to the coal could cause the condition observed.

Another example would be the dependence of a prominent sandstone body overlying a coal as being the sole criteria for identifying a seam. Sand bodies are formed by a number of different environmental elements that produce similar bodies when observed in small exposure or in a cursory manner. A sand deposited over a swamp by a landward migrating beach is quite different from the broad river and channel that migrates laterally across a swamp environment. Both will be different in orientation, geometry, areal extent, subsequent influence on swamp deposits and many other characteristics.

Therefore similar appearing materials and rock strata must be judged with caution, as should similar layering of rock types. As sea level fluctuates, the previously described beach may effectively shift back and forth across approximately the same geographic area. The result is an interfingering with landward type of sediments in one direction and tidal and marine in the other. The obvious result is that the surface of deposition at any one time will be receiving different sediments at different times. In the previously cited case of the swamp overriden by a beach, part of the swamp could conceivably at the same time be covered by a tidal area lagoon receiving fine muds. Therefore the coal overlain by sandstone in one place could be overlain by a shale nearby and yet be one and the same coal. The so called "layer cake" approach might suggest a different conclusion. Erosion by stream channels could completely disect a swamp environment leaving no continuity of plant remains between the segments of the severed swamp. Coal in the rock record may appear to be discontinuous and separate and perhaps two different coals. A similar conclusion might be drawn between two coals that were formed in distinctly separated swamps at the same time. Environments move not only geographically but upward with time, so in considering a sand body again, a high stratigraphic sand body could be lithologically continuous with a lower sand body or part of the same delta system with different geographic positions of the stream channels throughout the depositional history. Another way of explaining this is the segment of a river channel system that is a minor member of the system could appear high in the stratigraphic record yet be the same sand body formed by a more prominent channel

member of the same contemporaneous stream system that has eroded more deeply and appears lower in the section and close to, upon, or eroding a coal seam. Therefore it is important to recognize the environment, the types of materials, layering, interfingering of the materials, their removal by erosion, the resultant rock types, and the form of the rock bodies. Recognizing these environments and resulting rocks helps to explain the mystery of single coal seams appearing to merge or split into two or more parts. It helps to explain why a sandstone body is not always present or the varying characteristics of coals and other strata, and the difference in roof and bottom rocks. Familiarity with these principles of variability of environments, their sediments, and the resulting rock types will result in better correlations and better interpretations of structure and conditions explainable by the stratigraphy, and lead to more effective design and benefit from remedial measures.

Monongahela River Basin Stratigraphy - The vertical limits of study of the basin deal principally with the Pennsylvanian and Permian coal-bearing strata. These strata are somewhat repetitious or cyclical. They include muds, silt, sand, carbonate or lime, plant and animal fragments and material derived from older rock strata. These components may be mixed in different proportions. Some of the shales are comprised of delta, lagoon, and flood plain sediment. Siltstones are principally derived from delta, flood-plain or stream channel silts. Sandstones originate from offshore bar, stream channel, and beach sands. Limestones are impure or pure, massive or discontinuous and nodular and are derived from

lime muds of marine to brackish or fresh water environments. Fossils of plants and animals occur to varying degrees throughout all rock types owing to the prevalence of life at the time and the ability of the environment to preserve the once living matter. Plant fossils appear in such abundance in former swamp environments that coal is now found in numerous seams throughout the rock record.

The coal groups present in the Monongahela River Basin include all of the above characteristics but differ in general character from each other. The lowest Pottsville is represented by only the upper two of the tripartite series of strata present in southern West Virginia; which in ascending order are Pocahontas, New River and Kanawha. Sandstone is the most abundant rock type; shale and siltstone are common, conglomerate is sparingly present and limestone is absent. Although coals occur throughout the Pottsville, the most important are the Pocahontas coals (which) are missing in the basin. The general lack of coals in the New River lower section has led to the informal reference of lower unproductive beds and the prevalence of coals in the upper Kanawha section the reference of upper productive beds.

The Allegheny portion of the Pennsylvanian Age strata is the next higher assemblage and is comprised principally of shale, sandstone and coal, but marine and fresh water limestone are included. The latter are fewer and thinner in West Virginia. The importance of coals has caused these strata to be known as the Lower Productive Measures.

The overlying Conemaugh was originally called the Upper Barren Measures because such a small percentage of the known original coals present occurred in these strata. Gray and red

shale sandstone predominate but many tongues of limestone as thick as 20 feet may also occur.

The next higher, Monongahela, contains much limestone in Pennsylvania; up to 50% locally with the remainder comprised principally of shale, siltstone and sandstone. Southward, limestone becomes less prominent in WestVirginia where red shale becomes conspicuous and sandstones also become thicker and more prominent.

The uppermost Permian age rocks known as the Upper Barren Group or Dunkard are comprised of two portions; a Washington formation below and a Greene formation above. The predominant rock types are shale, shaly sandstone, and limestone. The Washington coal is the principal important seam although numerous coals appear throughout both formations. The limestones and coals disappear southward into West Virginia where red shale and sandstone predominate.

This great variety of rock types present does show some dominances horizontally and vertically as demonstrated by the above description of the numerous different beds within each subdivision of the Pennsylvanian and Permian strata and the broad differences among the subdivisions. The areal surface distribution of these subdivisions and their orientation and map patterns have been reviewed previously in the development of the structural character of the basin.

Analysis of Various Generalized Sections

Turning now to the vertical sectional analysis of the variations of the rock strata, some of the variety of materials and their layering, interfingering, transitional and thickness changes will be obvious.

Each portion of the Pennsylvanian and Permian age strata will be discussed by first indicating the source of a basic generalized stratigraphic column that was most complete for a framework of reference. Then several generalized sections from different parts of the basin will be described as to how they vary. In this way, along with inspection of the composite generalized sections, the variations in the strata throughout the Monongahela River Basin will be demonstrated in ascending order.

PENNSYLVANIAN AGE STRATA

POTTSVILLE - The Randolph County, West Virginia, generalized section was chosen as a basis for discussion. It is comprised of about 1075 feet of developed Pottsville but this is not the maximum development.

In southern West Virginia in McDowell County the Pottsville is thickest. The uppermost Kanawha group is 2,100 feet thick, the New River group 1,030, and the Pocahontas group 720 feet, totaling 3,850 feet. In Tucker County, adjacent to Preston County, the southwestward thickening begins to be obvious. Where there is double the Preston County thickness or 660 feet, the total is comprised of 385 feet of Kanawha, 275 feet of New River but no Pocahontas. In Randolph County, West Virginia, the Pennsylvania names are given precedent unless the horizons have been reliably

traced northward from the southern coal fields of West Virginia.

The Barbour-Upshur- Western Randolph generalized section is 1050 feet thick or 25 feet thinner. One difference is the Upper Chilton to Monitor sandstone interval where the Chilton, Cedar Run, and Alma coals; the Upper Cedar Grove and Peerless sandstones, along with several shales are represented only by 20 - 40 feet of greenish to gray, fissile clay to sandy shale. The Eagle to Gilbert coal interval also varies where the Decota, Grapevine and Lower Gilbert sandstones; Little Eagle and Lower War Eagle coals; and the Eagle and other shales are represented by 75 - 150 feet of sandstones and shales. However, two prominent sandstones are mentioned near the middle and base of the interval which probably are correlative. The Gilbert to Hughes Ferry coal interval is similarly undifferentiated and noted as 100 - 150 feet of sandstones and shales, as is the Hughes Ferry to Castle coal interval.

The Lewis-Gilmer Counties, West Virginia generalized section is substantially thinner measuring only about 700 feet. The Homewood sandstone to Lower Mercer coal section is a siliceous, dark, bony, section with marine fossils. The Mercer coal is recognized as a single horizon and between it and the Winifrede (Quakertown) coal, the Coalburg terminology is used. The Cleveland shale is used directly above the Chilton coal and from that point downward to the Gilbert coal no new terms are introduced, but several are missing. Below the Gilbert, the Lower Connoquenessing sandstone and Sharon coal terms are used with some question.

The Tucker County, West Virginia, generalized section is only 660 feet thick. In General the Quakertown (Winifrede) to Gilbert coal interval introduces the Winifrede limestone, Williamson coal

and Blackwater, Dingess shale and limestone terms but is missing the Cedar Grove, Alma, Campbell Creek (No. 2 gas), and Eagle coals with their associated sandstones and shales. The Gilbert shale is used between the Lower Gilbert sandstone and the Gilbert coal. Further the interval below the Gilbert coal appears to be missing many beds between it and the Upper Nuttall sandstone which is not split into an upper and lower part. From the Nuttall sandstone downward there is only one new term introduced. It is at the bottom where a lenticular Pineville sandstone is described. In addition several terms are missing.

The very incomplete and abbreviated 300 foot Marion-Monongalia-Taylor Counties, West Virginia generalized section has only 40 feet of strata beneath the Lower Connoquenessing sandstone where a Sharon coal streak is reported. The chief differences are that most beds and variety in strata are lacking. However, a Tionesta coal appears below the Homewood sandstone, followed by a Mt. Savage fire clay, clay and shale and coal streaks in four alternating layers downward to the Hammond fire clay.

The Preston County, West Virginia generalized section is 330 feet thick. The Homewood, Upper and Lower Connoquenessing and Sharon sandstones appear in descending order. The Tionesta coal appears below the Homewood and the Mt. Savage clay beneath the coal. The Mercer is divided into an upper and lower portion with 29 feet of sandy shale intervening. The Quakertown and Sharon coals are present. None of the Pottsville is preserved below the Sharon sandstone.

In the Garrett County, Maryland generalized section, the thickness ranges from 60 feet near the Pennsylvania state line in the Georges

Creek basin area, to 444 feet in the Tucker County, West Virginia area near the Maryland line. Across this region westward, the Allegheny thins slightly in its upper measures but thickens in the lower measures in response to basin deepening and conforms to a similar interpretation of the southwestward thickening of the Pottsville. In most respects, the similarities in variety and presence are strongly similar with Southern Somerset County, Pennsylvania. The Mount Savage coal group is interpreted as lying above the Brookville coal but the Lower Mount Savage is considered to be equivalent to the Brookville coal horizon, the base of which or the base of the underlying clay is the top of the Pottsville. In West Virginia, the Brookville is indicated in the Garrett County report to be equivalent to the Upper Mercer coal appearing in the generalized section of that area.

In the Brownsville-Connellsville Folio, Pennsylvania generalized section, the Pottsville is only 150 feet thick with the Homewood sandstone at the top, Mercer coal group in the middle and the Connoquenessing at the bottom lying on the Mauch Chunk. All of the lower Pottsville is missing.

In the Donegal Quadrangle, Pennsylvania, the generalized section is about 200 feet thick and comprised principally of massive, irregularly bedded sandstones. The Mercer coal and clay separate the uppermost Homewood sandstone from the Upper Connoquenessing sandstone. The Quakertown coal and clay lie above the Lower Connoquenessing sandstone which is underlain by the Sharon coal and clay group lying on top of the Mauch Chunk red shale. The Connoquesessing sandstones are about 150 feet thick and not always split. The Mercer interval is usually present and

about 20 feet thick and the overlying Homewood is about 30 feet thick. The lower part of the Pottsville is missing.

In the Fayette County, Pennsylvania generalized section, the section is 134 to 277 feet thick. The Homewood, Upper Connoquenessing and Lower Connoquenessing sandstones are well developed. The Homewood is recognized as an upper, cleaner, more massive sandstone and a lower, thicker, less clean and more complexly-bedded section. Mt. Savage is used for the Mercer clay and iron carbonate nodules are prominent above and below the Mercer coal. The Tionesta coal appears below the Homewood sandstone. The Sharon coal group is missing.

The southern Somerset County, Pennsylvania generalized section is from 80 to 200 feet thick. It is considered to be four formations which in descending order are the Homewood, Mercer, Connoquenessing, and Sharon which in total include seven subdivisions. There is upper and lower sandstone of the Connoquenessing separated by the Quakertown coal group; a Sharon coal group overlying the Sharon sandstone and no subdivisions for the other two formations. The Mercer clay is poorly developed and Mt. Savage is not applied to it but to the overlying Clarion which is considered to be equivalent of the Mt. Savage of Garrett County, Maryland.

The thickening westward and southward is very obvious in the Pottsville with a predominance of sandstone in the lower part of the New River group. The lowest Pocahontas group of the Pottsville is not developed in the Monongahela River Basin.

ALLEGHENY - The Barbour-Upshur-Western Randolph Counties, West Virginia generalized section was chosen for reference because of its thick 250 foot development.

The Lewis-Gilmer Counties, West Virginia generalized section is about the same thickness. The Lower Freeport sandstone lower division is probably correlative with the East Lynn sandstone. The Clarion sandstone term appears. The Upper Freeport limestone appears above the Upper Freeport sandstone. The Middle Kittanning and Clarion coals are missing. Clays are noted under the coals.

The Tucker County, West Virginia generalized section is 100 feet thinner, although most members are present. The East Lynn sandstone is developed below the Middle Kittanning coal rather than above. The Kittanning sandstone appears between the Lower Kittanning coal and the Clarion coal, and probably cuts the lower coal out in places.

Only the Upper Freeport, Lower Freeport and Johnstown limestones are present.

Clays are developed but less so than in Marion-Monongalia and Taylor Counties. Those present are the Bolivar clay below the Johnstown limestone and above the Middle Kittanning coal and beneath the Lower Kittanning coal.

The Marion-Monongalia-Taylor Counties, West Virginia generalized section is about the same thickness but shows a greater variety of lithologies.

The sandstones are all present and the Lower Freeport sandstone lower division equivalency to the East Lynn sandstonem above the Middle Kittanning coal appears to apply.

The greatest difference seems to be the appearance of several limestones: Upper Freeport, Lower Freeport, Johnstown, Vanport.

Clays, in addition to the Bolivar clay, seem to also become more abundant: below the Lower Freeport coal, beneath the Upper Kittanning coal, below the Johnstown limestone, the Lower Kittanning clay and the Clarion clay.

In the Preston County, West Virginia generalized section the thickness is 260 feet and with about the same lithologic variety and presence.

The sandstones include the upper and lower divisions of the Lower Freeport sandstone with the latter resting on the Middle Kittanning coal. The Lower Kittanning sandstone is not developed, but the Clarion sandstone appears above the Clarion coal.

The Upper Freeport, Lower Freeport, Johnstown and Vanport limestones appear.

Clays are developed: Bolivar below the Upper Freeport coal, below the Lower Freeport coal, below the Upper Kittanning coal: Hardman below the Johnstown limestone, below the Lower Kittanning coal, and below the Clarion coal.

All of the coals are present, and the Middle Freeport coal sometimes is contained in the Upper Freeport sandstone. The Brookville coal is seldom found beneath the Clarion clay.

The Brownsville-Connellsville Folio, Pennsylvania generalized section is about the same thickness and with equal variety. The lower coal measures are reported as the Clarion-Brookville coal.

The Donegal Quadrangle, Pennsylvania generalized section is about 225 feet thick. It is considered in three portions in ascending order, Clarion formation from the base of the Brookville underclay to the base of the Lower Kittanning coal underclay,

Kittanning formation to the top of the Upper Kittanning coal, and Freeport formation to the top of the Upper Freeport coal.

The Upper Freeport sandstone and Lower Freeport sandstone are not recognized as such; but a Butler sandstone appears above the Lower Freeport coal, and a Freeport sandstone appears below the coal. An Upper Worthington sandstone occurs between the Upper and Middle Kittanning coals which may be equivalent to the Upper East Lynn sandstone. The East Lynn sandstone is not present between the Upper and Middle Kittanning coals but a Lower Worthington sandstone does appear there as does an unnamed sandstone above and below it. The lower sandstone cuts into the lower coal.

Limestones appear below the Upper Freeport coal, Lower Freeport coal, Upper Kittanning coal and Middle Kittanning coals.

Clays appear below the Upper Freeport coal, Lower Freeport coal, Upper Kittanning coal, Middle Kittanning coal, Lower Kittanning coal and Brookville coal.

The coals are largely present but neither the Middle Freeport or Clarion coals are indicated.

The Fayette County, Pennsylvania generalized section is about 150 to 250 feet thick, with great variety and presence of strata. The terminology is comparable to the Donegal Quadrangle, Pennsylvania but the term Upper and Lower Westernport sandstone is introduced above and below the Middle Kittanning coals which could be equivalent to the Upper and Lower Worthington sandstone. Most of the limestones and clays are present. The Clarion and Brookville coals are separately distinguished.

The Southern Somerset County, Pennsylvania generalized section is about 280 feet thick and also similar in variety and presence of strata and terminology comparable to the Donegal Quadrangle, Pennsylvania. The top of the Kittanning formation is carried to the bottom of the Upper Kittanning coal; however the Lower Freeport is distinguished as a group of seams and splits as is the Upper, Middle and Lower Kittanning. The Scrubgrass coal is introduced above the Clarion coal. Mt. Savage is associated with the Clarion clay.

The Southern Somerset County, Pennsylvania comments hold for the Garrett County, Maryland generalized section. The Mt. Savage group is used for the Clarion coal interval with Mt. Savage applying to the coal and clay but Clarion used for the sandstone near the base of the group.

The relatively uniform thickness of the Allegheny with increased clays and limestones is obvious.

CONEMAUGH - The Barbour-Upshur-Western Randolph Counties, West Virginia generalized section was chosen for reference because of its thick 610 foot development and broad similarities to sections over a wide area of the basin.

The Doddridge-Harrison Counties, West Virginia generalized section is about 590 feet thick or about 30 feet thinner. Although the Morgantown sandstone thickens, the loss of the Jane Lew sandstone and the thinning of the Mahoning sandstone more than account for the thinner section. The Upper and Lower Pittsburgh limestones appear. The Normantown and West Milford coals are missing.

The Lewis-Gilmer Counties, West Virginia generalized section is about 575 feet thick or about 45 feet thinner. The thinning can be accounted for by the wedging of the Mahoning sandstone which is separated into an upper and lower portion which lacks the Mahoning coal. The thin Upper Pittsburgh limestone appears sporadically and the Brush Creek limestone thins. The West Milford coal is missing.

The Tucker County, West Virginia generalized section is very well developed with 840 feet or about 1/3 greater in thickness. A Barton sandstone appears above the Elk Lick (Barton) coal and the Mahoning sandstone is split into an upper and lower portion. The Fairfax limestone along with shales and coal thicken the section from the Pittsburgh coal underclay to the Lower Pittsburgh sandstone. A Lower Pittsburgh limestone appears below the Little Pittsburgh coal. The Hoffman limestone appears below the Normantown coal. The Albright limestone appears below the Bakerstown coal. Other limestones are poorly represented, or not present. The Meyersdale term is used for shale above the Buffalo sandstone. An Upper and Lower Mahoning sandstone enclose a Sutton limestone accompanied by the Mahoning coal, Thornton clay and red shale. The Hoffman coal is added below the Normantown coal, but the West Milford coal is missing. The Mahoning coal appears and the other coals are present.

The Marion-Monongahela-Taylor Counties, West Virginia generalized section is about 600 feet thick or twenty feet thinner. The Pittsburgh limestone is split by the Pittsburgh coal into an Upper and Lower Pittsburgh limestone and sets on a shale. The Normantown coal is missing. The difference can be credited to the thinning of the Mahoning

sandstone and it is also split by the Thornton fire clay. The Clarksburg limestone is below instead of above the Lower Connellsville sandstone.

The Preston County, West Virginia generalized section is 640 feet or slightly thicker. The section is very similar but the Normantown coal is missing. The Mahoning coal and Thornton fire clay appear as do the Elk Lick, Ewing, and Albright limestones.

The Greene County, Pennsylvania generalized section is incomplete showing only a shale, Connellsville sandstone, shale and Morgantown (First Dunkard) sandstone in descending order and presumed to be underlain by a weathered, thin coal and shale. This would appear to be a comparable thickness but lacking the variety of strata including the Little Pittsburgh, Little Clarksburg and Normantown coals. The lower coal mentioned might be the Elk Lick coal.

In the Brownsville-Connellsville Quadrangle, Pennsylvania the generalized section is approximately equally thick but coals are poorly developed and the Ames limestone is so fossiliferous it is described as crinoidal, suggesting perhaps a marine environment dominated. The Donegal Quadrangle reports the Ames as the highest known marine limestone in Pennsylvania.

In the Donegal Quadrangle, Pennsylvania, generalized section is estimated to be about 750 feet thick. This 150 foot thicker sequence is primarily a red bed sequence with sands. The Meyersdale red beds term appears for the Bakerstown coal to Buffalo sandstone interval and includes the Pine Creek limestone. The sandstones are all represented. Limestones and coals are relatively undeveloped. The Franklin coal term is used and is probably equivalent to the Little Clarksburg coal. The Wellersburg coal is present but the Duquesne coal is absent.

The Fayette County, Pennsylvania generalized section is about the same thickness. In descending order it has been divided into nine parts: an unnamed interval from the bottom of the Pittsburgh coal to the Lower Pittsburgh limestone, the Connellsville to the Little Clarksburg coal, the Lonaconing to the Lonaconing coal lenses and clay, the Morgantown to the Barbour coal, the Barton to the Birmingham shale, the Grafton to the Harlem coal, the Saltsburg to the Bakerstown coal, the Buffalo to the Brush Creek coal, and the Mahoning to the Upper Freeport coal.

The sandstones are present and well developed except the Grafton and Jane Lew sandstones. The Mahoning is divided into a roughly equal upper and lower sandstone with an intervening 2 foot clay or up to 24 feet of multiple coal, clay, and limestone beds.

An Upper and Lower Pittsburgh limestone are present but are thin and widely separated by the Lower Pittsburgh sandstone and Little Pittsburgh coal. The Clarksburg limestone is developed but may be separated into two beds by up to 20 feet of Clarksburg red shale. The Elk Lick limestone is absent above the Birmingham shale but may be equivalent to a Barton limestone that appears there. The Ames limestone is totally absent as is the Orlando limestone. The Pine Creek limestone is absent but may be equivalent to the Cambridge limestone which appears above the Buffalo sandstone. The Mahoning limestones appear and other limestones are present.

The Washington red shale term is used with some doubt below

the Birmingham red shale. The Cambridge red shale term is introduced between the Upper Bakerstown coal and Woods Run limestone.

The Normantown, Elk Lick and West Milford coals are missing. The Lonaconing coal appears above the Morgantown sandstone and the Barton coal below it, which may be equivalent to the Elk Lick coal. The Wellersburg coal is missing. The Bakerstown coal is divided into a persistent Upper Bakerstown coal and a less persistent Lower Bakerstown (Thomas) coal by the intervening Cambridge shale and Woods Run limestone. The Mahoning sandstone split interval includes Upper, Middle and Lower Mahoning coal variable in presence and thickness and separated by clay and limestone. The Piedmont coal is introduced below the Lower Mahoning sandstone and the Upper Freeport rider coal appears above the Uffington shale. Both are variable in presence and thin.

In the Pittsburgh Quadrangle, Pennsylvania the portion of generalized section still present in the area is only about 2/3 the thickness of the Marion-Monongalia-Taylor Counties, West Virginia generalized section. It thins from west to east mainly at the expense of the lower part of the section. The Connellsville sandstone is highly variable in thickness and the Lower Connellsville is missing. The Grafton sandstone is very thin but the Saltsburg sandstone thickens considerably, whereas the Mahoning sandstone is quite variable. From the Morgantown upward to the Connellsville and downward to the Birmingham sandstone there is a great deal of variation, because the Morgantown is reported to merge with the other sandstones. The thickened Saltsburg sandstone is also interesting because it is considered to be in two or three parts; an upper shaly

sandstone, shale or clay equivalent of the Jane Lew sandstone of West Virginia; a central member between the Bakerstown coal and Woods Run limey-shaly horizon; and a more persistent lower bed between the Woods Run horizon and Pine Creek limestone but which may be represented by a shale. The variably thick Mahoning sandstone is also interesting because of its variable vertical position. Normally considered to be located between the Brush Creek and Mahoning coals, it is frequently identified between the Mahoning and Freeport coals and is known to cut out the Freeport coal and rest upon deeper strata.

Limestones are as prominent even though the Pittsburgh, Ewing and Woods Run limestones appear, for they are all poorly developed as is the Ames and the others. The Wellersburg and Duquesne limestones appear between the Morgantown and Grafton sandstones but they are very thin.

The Normantown coal is absent from above the Morgantown Sandstone, as are the Elk Lick and West Milford coals between the Morgantown and Grafton sandstones. However, the Wellersburg and Duquesne coals appear there as thin seams.

The Southern Somerset County, Pennsylvania generalized section is 50% thicker or about 900 feet and is the thickest development in Pennsylvania. The section has been described as two formational parts. In descending order they are the Glenshaw formation from the top of the Ames limestone upward being the highest marine horizon in Pennsylvania, and the Casselman formation from the top of the Ames limestone downward.

The only principle sandstones in descending order are the probable Lonaconing sandstone lying about 155 feet below the Pittsburgh coal and the Morgantown sandstone. The lowest sandstone, lying on the Ames limestone, is the Grafton which is subdivided to an Upper and Lower sandstone with intervening shales, limestone and coal. The Saltsburg sandstone is lenticular and occasionally cuts out the Upper Bakerstown coal. The Buffalo sandstone is present in some places as is the Corinth sandstone which appears below the Brush Creek clay and shale. The Mahoning sandstone is well developed and may appear as upper and lower parts in places.

The Niverton shale appears as an interval split of the Clarksburg limestone. The Friendsville shale appears as part of the interval split of the Bakerstown coal and lies on the lower coal.

The Lower Pittsburgh limestone is present, and an Upper and Lower Clarksburg limestone occurs with intervening shale and coal. The Wellersburg limestone is present but grades into shale in places. The Barton limestone appears above the Birmingham shale. The Ames limestone overlies an Ames coal and the Lavansville limestone appears directly above it. The Ewing limestone is present. Beneath the Lower Bakerstown coal the Thomas underclay grades into the Albright limestone in places. The Cambridge limestone appears above the Buffalo sandstone. The Brush Creek limestone is present and the Brush Creek clay grades into the Irondale limestone in places. The Orlando, Woods Run and Pine Creek limestones are missing. The Woods Run may be represented by the Friendsville shale.

The Little Clarksburg, Normantown, Elk Lick, West Milford, and Harlem coals are missing. The Little Clarksburg may be equivalent to the Upper Clarysville coal. The Elk Lick and West Milford are occupied by the Wellersburg-Barton coals interval. Several coals appear. The Morgantown coal appears between the Little Pittsburgh and Pittsburgh coals. In descending order between the Little Pittsburgh limestone and Morgantown sandstone they are: an unnamed coal, Franklin "rider" coal, Franklin coal, unnamed coal, Lonaconing coal, Hoffman coals in two splits, Upper and Lower Clarysville coal. The Wellersburg coal appears below the Morgantown sandstone. A Barton "rider" coal and a Barton coal appear above the Birmingham red beds. The Upper and Lower Grafton sandstone interval include a Federal Hill "rider" coal and a Federal Hill coal. The Ames coal appears below the Ames limestone, the Bakerstown coal appears as an Upper and Lower split. The Humbert coal appears above the Upper Mahoning sandstone. An Upper and Lower Mahoning coal are present within the sandstone. An Upper Freeport "rider" coal is present in the lower portion of the sandstone.

In the Garrett County, Maryland generalized section the terminology is closest to the Southern Somerset County, Pennsylvania generalization section. The section is about 825 - 925 feet thick. The section is considered as an upper part from the Barton coal upward and a lower part from the Barton coal downward. This demarcation line is about 100 feet above the Ames horizon marker of the Southern Somerset County, Pennsylvania area. This point is near the top of the Ames limestone. Most of the upper member is missing.

The sandstones present and terminology are the same.

The Barton limestone is well developed, but the Ames and Cambridge appear to be mainly shales. The Albright limestone is well developed as is the limestone at the Lavansville horizon, but the term is not used. The Irondale limestone also seems to dominate the Brush Creek clay horizon. The Mahoning limestone is present but poorly developed.

The coals present and terminology are the same except that the Federal Hill "rider" coal and the Humbert coal are missing.

The trend to thickening towards the northeast, the increase of freshwater limestones, redbeds and coal splits is obvious, also the predominance of these rock type characteristics in the Upper Casselman formation over the Lower Glenshaw formation.

MONONGAHELA - The Barbour-Upshur-Western Randolph Counties, West Virginia generalized section was chosen for reference because of its good development of 400 feet.

The Lewis-Gilmer Counties, West Virginia generalized section is about the same thickness and nearly identical. The Uniontown limestone is notably thinner, the Fulton shale is not recognized as such, and the Benwood limestone is represented as limestone nuggets only, both occurring immediately above the Upper Sewickley sandstone.

The Doddridge-Harrison Counties, West Virginia generalized section is about the same thickness, but about 10 feet thicker. The thickening appears to be the net result of the loss of the Cedarville and Weston sandstones in the lower part of the section, even though the Upper Pittsburgh sandstone appears there and the other sandstones thicken but at the expense of the shales. The

The limestones also thicken notably. The Waynesburg limestone and Waynesburg coal are added in the upper part of the section.

The Tucker County, West Virginia generalized section is largely lacking owing to erosion. The Upper Pittsburgh sandstone is the highest member preserved and the only difference is the presence of the Pittsburgh rider coal beneath the sandstone and above the shale between it and the Pittsburgh coal.

The Marion-Monongalia-Taylor Counties, West Virginia generalized section is 10 feet thicker. Although the Cedarville and Weston sandstones are missing, the Upper Pittsburgh appears and the other sandstones thicken. The Waynesburg limestone appears and the Uniontown but principally the Benwood thickens at the expense of shales to account for the slightly thicker section.

The Preston County, West Virginia generalized section is missing except for some Upper Pittsburgh sandstone and Pittsburgh coal.

The Greene County, Pennsylvania generalized section is substantially thinner ranging from 280 - 380 feet. Shales and sandstones are less well developed. Limestone has thickened notably especially the Benwood limestone, which indicates a less clastic environment receiving fewer sediments, thus a thinner section exists.

The Pittsburgh Quadrangle, Pennsylvania generalized section is thinner, ranging from 210 - 340 feet. Sandstones are largely absent and limestones predominate. The Benwood is especially thick and the Fishpot limestone appears here as well as in the Amity Folio, Pennsylvania generalized section.

The Donegal Quadrangle, Pennsylvania generalized section shows the predominance of numerous gray dense limestones from the top of the Sewickley coal upward 115 feet. The section is therefore thinner. The thinning of the section northward and the increase in abundance of limestone is obvious.

PERMIAN AGE STRATA

DUNKARD - The Marion-Monongalia-Taylor Counties, West Virginia generalized section was chosen for reference because of its thick 1180 foot development and variety of rock units.

The Lewis-Gilmer Counties, West Virginia generalized section is 179 feet thicker or 550 feet thick and perhaps some of the section is missing. The Rush Run sandstone to Hundred sandstone interval thickens by 30 feet.

From the Hundred sandstone to the Creston shale the interval thickens 20 feet. The Hundred coal above and the Washington "A" coal below the Upper Marietta sandstone are missing and shales predominate.

From the Creston shale to the Washington coal the interval decreases by 9 feet chiefly because of the lack of the Middle and Lower Washington limestones above and below the Lower Marietta sandstone.

From the Washington coal to the Mannington sandstone the interval thickens 19 feet. Although the section has thickened it is chiefly fire clay and shale at the expense of the Bristol limestone, Washington sandstone and Little Washington coal.

The Doddridge-Harrison Counties, West Virginia generalized section is about the same thickness, 1180 feet with the Greene formation about twice as thick as the Washington formations in each case and roughly equal to each other: Greene from 791 and 793 feet, Washington from 389 and 387 feet. One notable difference is the interval between the Windy Gap limestone and Windy Gap coal. This interval is the same thickness, but the St. Cloud sandstone and a shale have changed to a predominantly shale section.

The Gilmore limestone to Lower Rockport limestone interval thickens by only about 10 feet. It contains an alternate limestone, sandstone and shale sequence whose comparable members thicken and thin at the expense of each other. Where one strata has thinned the adjacent strata has thickened and vice-versa. In addition, the Nineveh "A" coal is missing.

The Fayette County, Pennsylvania generalized section shows the Washington formation section to be about equivalent in thickness. The chief differences are that the section includes more named sandstones and to a lesser degree limestones. There seems to be some discrepancy in the interval between the Upper Washington limestone to the Upper Marietta sandstone. This interval includes the Jollytown, Brier Hill and Davistown sandstones which appear above the Upper Washington limestone in West Virginia. The same is so for the Amity, Pennsylvanis Folio but Greene County, Pennsylvania agrees with West Virginia. The Middle Washington limestone appears above the Upper Marietta sandstone but above the Lower Marietta sandstone in West Virginia.

The Greene County, Pennsylvania generalized section is about 200 - 370 feet thinner. The section includes an equal variety of beds but has fewer of all types. It is missing the Gilmore coal and Nineveh coal. It contains the Tenmile coal at the same horizon as the Jollytown coal.

The Claysville Quadrangle, Pennsylvania generalized section is about 90 feet thicker in the Greene formation as there are more limestones present including the Claysville, Prosperity and Donlevy. The Tenmile coal also appears. The Washington formation section is about 120 feet thinner just the opposite of the Greene formation. The main difference appears to be more numerous limestones suggesting less clastic deposition, thus less muds and sands, therefore, less thickness.

Very little of the Permian is preserved in the area of the Brownsville-Connellsville Folio, Pennsylvania.

The Pittsburgh Quadrangle, Pennsylvania generalized section is incomplete and 80 to 110 feet thinner. Although correlations are not clear it appears that several limestones, sandstones and coals are missing with only the Mount Morris limestone appearing above instead of below the Waynesburg split. Therefore the Waynesburg coal (upper split) is maybe correlative with the Waynesburg "A" coal. The two massive sandstone beds above and below the Waynesburg upper split may be correlative with the Mannington and Mt. Morris sandstones.

The lesser thickness of the Dunkard in the north is obviously due to the lack of a complete section and the predominance of thin coals and limestones and numerous sandstones.

Significance of Stratigraphy - From the foregoing the complexity of the basin is revealed. Hopefully, it is now possible to avoid the "layer cake" concept of stacked, wide spread, uniformly bedded strata and more clearly approach an understanding of the splitting of coals and merging and gradation of seams and variations in overlying and underlying rock. Recognizing the horizontal and vertical migration of depositional environments and their consequential interfingering and migration through the geologic section of rock types may sharpen analysis of the local situation and contribute to a more effective design of remedial measures in the following ways:

Better correlation of coal strata by recognizing these stratigraphic complexities and a more accurate prediction of water flow patterns and water quality relative to rock types.

Predictions of rock types and their anticipated bearing and shear strength could suggest more effective location for mine seals and their emplacement and design for better service and permanence. Some estimate might be made of the value and permanence of subsidence crack treatments.

The identification and orientation of ancient geologic environments might be useful in predicting the location and magnitude of sand bodies and their relation to grading during surface remedial measures. Shales may be predictable as to sulfuritic character relative to surface grading methods and in some instances sulfuritic sandstones also. Clays may be predictable from shale and claystone horizons beneath the coals as remedial materials. Limestone might also become important in this manner.

As to future of the basin, all of these stratigraphic features should be considered in the development of the coal seams as well as abatement and remedial plans to control deterioration of water quality in the basin.

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GENERALIZED STRATIGRAPHIC SECTION OF THE COALS

OF THE MONONGAHELA RIVER BASIN*

Age	Rock Unit	Formation	Coal	Location **
Permian	Dunkard	Greene	Windy Gap	10, 9, ;
			Gilmore	10, 9
			Nineveh "A"	9
			Nineveh	9, 5, 1
			Hostetter	10, 9
			Fish Creek	10, 9, 1
			Dunkard	10, 9, 5, 1
			Tenmile	1
			Jollytown (Tenmile of some reports)	10, 9, 1, 15
		Washington	Hundred	10, 9
			Washington "A"	10, 9
			Blacksville local coals	2
			Washington Rider	
			Washington	1, 3, 9, 10, 11, 15
			(Brownsville)	11
			Little Washington	10, 9
			Waynesburg "B"	1
			Waynesburg "A"	10, 9, 1, 3, 15

*Where coal names repeat they reflect where the literature indicates that the names have been used locally for different seams.

(**See p. 65 for index of locations)

Age	Rock Unit	Formation	Coal	Location**
Pennsylvanian	Monongahela		Waynesburg (Mt. Morris)	15, 12, 11, 10, 9, 6, 1, and 3
			(Koontz)	15
			Little Waynesburg	10, 9, 1
			Uniontown	15, 12, 11, 10, 9, 7, 3, 2, 1
			Lower Uniontown	12, 10, 9
			Benwood	2
			Sewickley	15, 12, 11, 10, 9, 3, 2, 1
			(Mapletown,	1
			Five Foot,	2
			Tyson,	4, 15
			Berlin, Gas,	4
			Sewickley Creek,	3
			Upper Sewickley)	15
			Lower Sewickley	15, 4
			Redstone Rider	4
			Redstone	12, 11, 10, 9, 7, 3, 2, 1
			(Pine Hill #1,	4
			Redstone Creek,	2
			Eighty Foot)	3
			Pittsburgh Rider	14, 2
			(Blue Lick, Berlin,	4
			Redstone, Dirty Five)	4
			Pittsburgh	15, 14, 12, 11, 10, 9, 8, 7, 4, 3, 2, 1
			(Big Vein,	4, 15
			Pine Hill #2,	4
			Youghiogheny, Penn Gas,	3
			Irwin Basin, Murraysville,	3
			River,	1, 5
			Irwin Gas, Greensburg,	2
			Latrobe, Upper Connellsville,	2
			Connellsville,	2

Age	Rock Unit	Formation	Coal	Location **
Pennsylvanian	Monongahela		Pittsburgh (Cont'd)	
			(Big Red, Price, Elk Garden, and Fourteen Foot)	4, 6 15 15, 7
Pennsylvanian	Connemaugh	Casselman	Morgantown	14, 13, 7, 4
			(Dirty Six)	4
			Little Pittsburgh	15, 14, 12, 11 9, 8, 7, 4, 3, 2
			(Saylor, Five Foot)	4
			Second Little Pittsburgh	7
			Franklin Rider	4
			(Third Little Pittsburgh)	7
			Little Clarksburg ***	15, 14, 12, 11, 9, 8, 7, 2
			(Franklin,	15, 14, 13, 7, 4
			Bavington,	4
			Six Foot,	4
			Dirty Nine Foot,	15, 7
			Lower Clarksburg,	3
			and Clarksburg)	2, 3
			True Elk Lick	7
			Normantown	14, 13, 12, 11
			(Upper Hoffman,	14, 13
			Upper & Lower Dunkard)	1
			Middle Hoffman	14, 13, 7
			Lower Hoffman	7, 4
			Upper Clarysville	7, 4
			Lower Clarysville	7, 4

***The Little Clarksburg appears to be associated by name or actual horizon at different places with the range of coals from the Franklin Rider to the Lower Clarysville.

Age	Rock Unit	Formation	Coal	Location **
Pennsylvanian	Conemaugh	Casselman	Lonaconing	7, 4
			(Elk Lick, Four Foot)	4
			Wellersburg Rider	7
			Wellersburg	7, 4, 3, 2
			(Twin, Split Six, Berlin, Top Seam, Weller Bed)	7, 4 4 4
			Barton Rider	7, 4
			Elk Lick	14, 13, 12, 11 9, 8, 7, 4
			(Barton, Four Foot, Lonaconing, and Bakerstown)	15, 14, 13, 7,4 15, 7, 4 7 15
			West Milford	12, 9
			Duquesne	6, 2
			Federal Hill Rider	4
			Federal Hill	7, 4
Pennsylvanian	Conemaugh	Glenshaw	Ames	4
			(Friendsville, Crinoidal)	15 15
			Harlem Rider	7
			Harlem	14, 13, 12, 11, 9,8,7,4,3,2
			(Platt, Fossil, Weller)	4 4
			Hager	2
			(Painter)	3
			Upper Bakerstown	14, 13, 12, 11, 9,8,7,4,2
			(Maynadier, Elk Lick, Barton)	7 4 6

Age	Rock Unit	Formation	Coal	Location **
Pennsylvanian	Conemaugh	Glenshaw	Lower Bakerstown	14, 13, 12, 11, 9, 8, 7, 4, 3, 2
			(Thomas,	14, 13, 4, 7
			Three Foot, Four Foot,	7
			Honeycomb,	7, 4
			S Silver Valley)	4
			Grantsville	7
			(Beachy)	7
			Coleman	4
			(Pine Creek)	6
			Philson	4
			Rock Seam	4
			Woods Run	2
			Brush Creek Rider	7
			Brush Creek	14, 13, 12, 11, 9, 8, 7, 4, 3, 2
			(Farmington,	2
			Masontown)	15
			Humbert	4
			(Rose Bed)	4
			Upper Mahoning	14, 8, 9, 2
			(Mahoning,	14, 7, 4
			Gallitzin)	7
			Middle Mahoning	14, 8, 8, 2
			(Six Foot)	13
			Lower Mahoning	14, 9, 8, 2
			Piedmont	7
			(Six Foot)	7
			Upper Freeport Rider	7, 4
			(Davis Rider)	7

Age	Rock Unit	Formation	Coal	Location**
Pennsylvanian	Allegheny	Freeport	Upper Freeport	15, 14, 13, 12, 11, 9, 8, 7, 4, 3
			(Split-Six, Corinth,	15
			Grantsville, Beachy,	15
			Davis,	14, 13, 7
			Coke Yard, Johnstown,	3
			Four Foot, Reid,	3
			Lockport, Bolivar,	3
			Hugus,	4
			Sandrock,	7
			Saw Mill,	4
			Thick Freeport,	6
			Double Freeport,	6
			Thomas, Three Foot,	15
			"E")	2
			Middle Freeport	8
			Lower Freeport Rider	4
			Lower Freeport	14, 13, 12, 11, 9, 8, 7, 4, 3
			(Barrelville,	7
			"D",	2
			and Parker)	7
			Montell Rider	7
		Kittanning	Upper Kittanning	14, 13, 12, 11, 9, 8, 7, 4, 3
			(Montell,	7
			"C",	2
			Bluebaugh,	7
			Westernport,	7
			Brookville)	7
			Little Montell	7
			Piney Mountain	7
			Middle Kittanning	14, 13, 12, 9, 7 4, 3
			(Six Foot, Davis, Luke,	7
			"C",	2
			Bender, Whiterock,	15
			and Four Foot)	15
			Lower Kittanning Rider	3

Age	Rock Unit	Formation	Coal	Location **
Pennsylvanian	Allegheny	Kittanning	Lower Kittanning ****	15, 14, 13, 12, 11, 9, 8, 7, 4, 3
			(Ellerslie,	7
			Six Foot,	7, 15
			Five Foot,	7
			Davis,	15
			"B")	2
			"Ferriferous"	8, 3
			Scrubgrass	7, 4
			(Split Six)	15
			Clarion	14, 13, 12, 9, 8, 7, 4, 3
			(Mt. Savage,	7
			Parker,	15
			"A")	2
			Brookville	15, 7, 4, 3
			(Lower Mt. Savage,	7
			Bluebaugh,	15
			"A",	2
			Montell)	
			Upper Mt. Savage	7
			(Westernport, Two Foot)	15
			Lower Mt. Savage	7
			(Bloomington, Railroad)	15
	Pottsville	Kanawha	Tionesta	9, 8
			Upper Mercer	14, 13, 9, 8, 7, 4, 3
			(Mt. Savage)	7
			Lower Mercer	13, 12, 11, 9, 8, 7, 4, 3
			(Stockton)	11, 12, 13

**** The Lower Kittanning has been identified from the Quakertown to the Montell in Maryland.

Age	Rock Unit	Formation	Coal	Location **
Pennsylvanian	Pottsville	Kanawha	Quakertown Rider	14, 13, 12, 7, 4
			(Coalburg)	11, 13
			Quakertown	14, 13, 12, 9, 8, 7, 4, 3
			(Winifrede)	11, 13, 14
			Williamson	14
			Chilton	13, 12, 11
			Cedar Grove	13, 12, 11
			Alma	13, 12
			Campbell Creek	13, 12, 11
			(Peerless, Peerless Bench, No. 2 Gas)	13 13 11, 12
			Powellton	13, 12, 11
			(Brownstown)	12
			Eagle	13, 12, 11
			(Middle War Eagle, Gimmel)	
			Little Eagle	13
			Lower War Eagle	13, 11
			Gilbert	14, 13, 12, 11
			Douglas	13
			Lower Douglas	13
		New River	Iaeger "B"	13
			Hughes Ferry	14, 13, 12, 11
			(Sharon, Lower Douglas)	11
			Lower Iaeger	13, 12
			Castle	14, 13, 12
			Sewell "B"	13, 12
			Sewell "A"	13

Age	Rock Unit	Formation	Coals	Location **
Pennsylvanian	Pottsville	New River	Sewell	14, 13, 12
			(Sharon, Davy, New River, Pocahontas)	11, 12, 13, 14, 8, 7, 4, 3
			Welch	14, 13, 12
			Little Raleigh	13
			Beckley	13
			Fire Creek (Quinnimont)	14, 13
			Little Fire Creek	13

** Index to Areas Where Coal Names and Name Equivalents Appear

1. Greene County, Pennsylvania
2. Fayette County, Pennsylvania
3. Westmoreland County, Pennsylvania
4. Somerset County, Pennsylvania
5. Washington County, Pennsylvania
6. Allegheny County, Pennsylvania
7. Maryland, per Waage and Toenages, see Bibliography
8. Preston County, West Virginia
9. Marion-Monongalia-Taylor Counties, West Virginia
10. Doddridge-Harrison Counties, West Virginia
11. Lewis-Gilmer Counties, West Virginia
12. Barbour-Upshur-Western Randolph Counties, West Virginia
13. Randolph County, West Virginia
14. Tucker County, West Virginia
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Reger, D. B. (1931) Preston County, West Virginia Geological Survey, County Report.

COMPOSITE STRATIGRAPHIC SECTION OF ROCK STRATA

OF THE MONONGAHELA RIVER BASIN

Age	Rock Unit	Formation	Thickness in feet and Description
Permian	Dunkard	Greene (Some important beds below)	
		Upper Proctor sandstone	(40) Flaggy.
		Shale	(15)
		Middle Proctor sandstone	(25)
		Shale	(10)
		Lower Proctor sandstone	(25) Massive, green, micaceous.
		Shale	(35) Red and variegated.
		Windy Gap limestone	(5).
		St. Cloud sandstone	(20)
		Shale	(4) Sandy.
		Windy Gap coal 3" to	(1) Slaty.
		Fire clay	(80) Shale, red and variegated, with thin layers of sandstone and limestone.
		Gilmore sandstone	(30) Massive, coarse, sometimes forms cliffs.
		Gilmore coal	(1)
		Gilmore limestone	(1)
		Shale	(93) Variegated and red with thin sandstone.
		Sandstones*	(5) Thin.
		Upper Rockport limestone	(5 - 30)
		Taylor sandstone	(5 - 30)
		Middle Rockport limestone	(5 - 30)

Age	Rock Unit	Formation	Thickness in feet and Description
Permian	Dunkard	Sandstone and shale	(5 - 29) Buff and red.
		Nineveh "A" coal 3" to	(1)
		Lower Rockport limestone	(5 - 15)
		Shale and sandstone	(15 - 25) Brown, variegated, limy.
		Nineveh sandstone	(5 - 25) Massive, coarse and brown.
		Shale 1" to	(4)
		Nineveh coal	(1)
		Fire clay and shale	(5 - 10) Limy.
		Nineveh limestone	(5 - 30)
		Shale	(30) Variegated and red.
		Burton sandstone	(29) Massive.
		Hostetter coal	(1)
		Shale	(60) Sandy with thin sandstone.
		(Claysville limestone)*	(Lenticular appears about midway between Nineveh and Dunkard in Claysville, Folio, Pennsylvania.
		Fish Creek sandstone	(35) Massive, light gray to greenish, weathers to greenish tan, medium-grained, arkosic.
		Fish Creek coal	(1)
		Fish Creek fire clay	(5)
		Shale	(29) Sandy and red with thin sandstones.
		Ten Mile coal*	Appears 10 feet above Jollytown in Claysville, Folio, Pennsylvania, also in Greene County, Pennsylvania.
		Rush Run sandstone	(25 - 40) Massive, soft, brown, micaceous.
		Shale	(5-10) Sandy, red.
		Dunkard coal	(1)
		Prosperity limestone*	Appears about 25' below Dunkard, Claysville, Folio, Pa., lenticular.

Age	Rock Unit	Formation	Thickness in feet and Description
Permian	Dunkard	Fire clay and shale	(29) Red, sandy and variegated, Donley limestone at this horizon and is 20' in Claysville Folio, Pennsylvania.
		Donley limestone	(20)
		Jollytown sandstone	(20 - 30) Massive, brown.
		Washington (Some important beds below)	
		Upper Washington limestone	(4 - 15) Single-bedded when thin, inter-bedded with shaly limestone and shale where thick, brittle, blue to black and mottled weathering to distinctive gray-white. Outcrop, commonly weathered to regularly rounded blocks.
		Jollytown limestone	(5) Hard, coarse, brecciated, weathering to dull gray, yellow-tinged, rough surface about 20-40' below Washington limestone.
		Brier Hill sandstone *	(10 - 30) Above the Jollytown in Fayette County, Pennsylvania.
		Jollytown coal (Ten Mile coal at Greene County, Pa.)	(1) Commonly overlain with nodules of iron carbonate.
		Fire clay	(1)
		Davistown sandstone *	(10 - 30) Present in Fayette County, Pennsylvania.
		Shale*	(30) Sandy, variegated with thin sandstone.
		Shale	(5) Limy.
		Hundred sandstone	(34 - 40) Coarse, soft, brown.
		Hundred Coal 5"	
		Fire clay and shale	(35 - 50) Red, variegated, sandy.
		Middle Washington limestone	(5) Appears above Upper Marietta in Fayette County, Pennsylvania, and above the Lower Marietta in Marion MOnongalia and Taylor Counties, West Virginia.

Age	Rock Unit	Formation	Thickness in feet and Description
Permian	Dunkard	Upper Marietta sandstone	(0 - 50) Massive or flaggy. micaceous.
		Washington "A" coal	(1)
		Lower Washington limestone*	(0 - 5)
		Creston shale	(45 - 60) Red, sandy.
		Middle Marietta sandstone and local coals*	(5 - 30) In Fayette County. Pennsylvania.
		Blacksville limestone and local coals*	(5 - 20) In Fayette County, Pennsylvania.
		Lower Marietta sandstone	(40 - 50) Massive or flaggy, micaceous.
		Washington Rider coal*	(0 - 12)
		Lower Washington limestone	(2 - 17)
		Washington coal	(1 - 4)
		Washington fire clay shale	(8 - 30) Yellow.
		Bristol limestone	(0 - 4)
		Washington sandstone	(0 - 35)
		Little Washington coal	(0 - 4) Described as equal to Waynesburg "B" coal in Greene County, Pennsylvania, report.
		Shale	(5 - 20) Red and sandy.
		Upper Mannington sandstone (Waynesburg "B" coal horizon near Middle	(5 - 50) Massive, soft, brown, coarse. (0.5 - 2)
		Lower Mannington sandstone*	(0 - 6)
		Woodglen limestone*	(0 - 9)
		Colvin Run limestone*	(0 - 12)
		Shale	(4)

Age	Rock Unit	Formation	Thickness in feet and Description
Permian	Dunkard	Waynesburg "A" coal (Possibly the Waynesburg Upper Split of the Pittsburgh Quadrangle, Pennsylvania)	(1 - 5)
		Fire clay and shale	(3)
		Upper Mt. Morris limestone	(0 - 10) Lenticular.
		Mt. Morris sandstone*	(0 - 10)
		Lower Mt. Morris limestone*	(0 - 10)
		Shale	(12 - 30) Variegated, sandy.
		Waynesburg sandstone	(10 - 60) Usually in two equal beds separated by sandy shale, coarse-grained, light to yellowish gray or buff, cross-bedding common, massive to flaggy, occasionally pebbly and brown or represented by shale.
		Elm Grove limestone	(3) Dark, flaggy.
		Cassville shale	(5) Dark, sandy with fossil plants. May be cut out by Waynesburg sandstone which then sets on Waynesburg coal.

* Variations from the generalized section in the Marion-Monongalia-Taylor Counties report by the West Virginia Geological Survey.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Monongahela	Waynesburg coal	(1) Soft and occasionally massive and hard where it is medium-bedded, brown, micaceous; some limestone lenses and thin sands in Pennsylvania. (10-25) Greenish to brown, shaly, flaggy.
		Gilboy sandstone	
		Little Waynesburg coal*	(5) Present in Doddridge - Harrison Counties.
		Waynesburg limestone*	(4-10) Light-colored, heavy-bedded, persistent lying within alternating sandstone and shales. In Fayette County, Pennsylvania, a lower bench 10-25' is separated by 5-6' of shale from an upper 0-13' bench.
		Shale	(5-15) Dark, sandy, fissile.
		Uniontown sandstone	(0-40) Greenish-gray, flaggy with numerous mica particles; may be absent in Pennsylvania.
		Annabelle shale	(10-45) Grayish at top - reddish at base and sandy throughout. In other areas, the Uniontown coal is generally found between red and gray shales.
		Uniontown coal*	(2) See above.
		Uniontown limestone	(0-5) Hard, gray, frequently represented as a nodular zone.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Monongahela	Shale	(20 - 40) Grayish to reddish and sandy.
		Arnoldsburg sandstone	(10 - 25) Greenish-gray, flaggy to massive, micaceous in Pennsylvania. Medium-grained, soft, gray brown and thin-bedded.
		Shale	(20 - 30) Reddish to brown with a carbonaceous horizon, frequently with a one foot coal bloom (Lower Uniontown).
		Lower Uniontown coal*	(1) See above.
		Fulton shale	(5 - 20) Fissile, sandy, greenish.
		Benwood limestone	(0 - 150) Thin, often shaly and frequently sandy, when thick it has lower division of 60 feet and upper division 6 - 20' of beds up to 1' thick in Greene County, Pennsylvania near Pittsburgh, Pennsylvania it is inter-bedded gray argillaceous limestone up to 50' thick separated by shale, clay shale, and sandstone.
		Benwood coal*	(1 - 2) In the middle of the Benwood limestone.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Monongahela	Upper Sewickley sandstone	(15 - 50) Generally massive, hard, gray, sometimes shaly and flaggy. One of the prime marker beds as it is consistent and readily recognized, often as a cliff former with the base located a fairly consistent 140' above the Pittsburgh coal.
		Sewickley coal (Upper and Lower in Somerset County, Pennsylvania and Maryland)	(0) Generally just below the Sewickley sandstone, frequently expressed in the section as a carbonaceous shale.
		Fishpot limestone*	Lenticular, but thick in Somerset County, Pennsylvania, extensive in Western Fayette County, Pennsylvania sometimes only limy nodules.
		Shale	(15 - 40) Gray, fissile, in Pennsylvania inter-bedded shale and clay, yellow to brown, thin-bedded and soft.
		Lower Sewickley sandstone	(15 - 40) Grayish, sometimes massive, often shaly and flaggy, in Pennsylvania brown and cross-bedded and may be absent and represented by shale.
		Sewickley limestone	(0 - 2) Hard, yellowish, lenticular, grading to nodular.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Monongahela	Shales	(5 - 20) Generally sandy and brecciated, sometimes reddish but more frequently yellowish to buff. Frequently contains thin sandstone stringers.
		Cedarville sandstone	(10 - 40) Generally greenish-gray when fresh becoming buff on weathering, ranges from massive, micaceous to a thin flaggy sandstone that is quite shaly. Occasionally very shaly and tends to grade into the overlying shales.
		Shale	(0 - 10) Generally light to dark, gray, fissile.
		Redstone Rider coal*	
		Redstone coal	(4-6) Generally single-bedded with little shale stringers or partings, frequently contains pyritic material. Usually 40 - 60' above the Pittsburgh coal.
		Shale	(5 - 15) Clay shale on top, rapidly grading downward into hard, fissile, sandy shale.
		Weston sandstone*	(20 - 50) Averages 25' in study area. Generally shaly and flaggy frequently represented by a very sandy shale.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Monongahela	Redstone limestone*	(2 - 20) Fresh water limestone, Gray on fresh surface, rapidly changing to buff on weathering. Generally massive, hard but frequently nodular. Very good marker bed.
		Upper Pittsburgh sandstone*	(6 - 35) Soft, coarse, light gray, highly variable with shale beds and grades into predominantly shale sections in Pennsylvania.
		Pittsburgh rider coal*	(0 - 5)
		Pittsburgh sandstone*	(2 - 35) Medium to hard, thin to medium-bedded, may be heavy-bedded.
		Weston shale*	(5 - 15) Hard, gray, fissile, sometimes sandy or limy.
		Pittsburgh coal	(0 - 16) Soft, with very thin partings that do not interfere with mining. Generally contains pyritic material and free sulfur balls. The faces of the open mines frequently were found to be coated with a very fine crystalline mineral (halotricite).

* Variations from the generalized section in the Barbour-Upshur, Western Randolph Counties, West Virginia report by the West Virginia Geological Survey.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Shale and clay	(5 - 10) Hard fissile shale, often a fire clay of fair quality.
		Fairfax limestone*	(2)
		Shale*	(3)
		Morantown coal*	(4" - 5') In Somerset County, Pennsylvania.
		Shale*	(35)
		Lower Pittsburgh sandstone	(15 - 50) Massive gray medium-grained and medium hard, frequently very shaly, flaggy sandstone in West Virginia. In Pittsburgh Quadrangle, Pennsylvania numerous beds, gray to greenish, sometimes carbonaceous interbedded with sandstone, shale, clay containing limestone nodules. Thickest most persistent bed occurs 25 - 40' below Pittsburgh coal.
		Shale	(3 - 8) Hard, gray, fissile shale.
		Upper Pittsburgh limestone*	(4) -
		Little Pittsburgh coal	(0 - 1) A thin coal bloom found 50' below the Pittsburgh coal. In Pittsburgh Quadrangle 9 - 52' below and in thin lenses.
		Fire clay and Shale*	(7) Gray.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Lower Pittsburgh limestone*	(10)
		Franklin Rider coal*	[illegible]
		Shale	(15 - 30) Hard, sandy, fissile, variegated, red.
		Connellsville sandstone	(20 - 50) Gray to brown, massive and frequently conglomeratic, sometimes shaly. In Pittsburgh Quadrangle, Pennsylvania, may merge with Morgantown below. It occurs as medium-grained, arkosic with muscovite, light gray weathering to yellowish to greenish, thin-bedded, lenticular with interbedded shales. In South Somerset County, Pennsylvania, it is in a shale section without the Connellsville sandstone.
		Little Clarksburg coal (Franklin coal of Maryland, Donegal Quadrangle Pennsylvania, South Somerset County, Pa.)	(0 - 2) Very shaly, splinty coal of no value. Generally present as a thin bloom approximately 80' below the Pittsburgh coal in the outcrop area.
		Lonaconing coal*	In South Somerset County, Pennsylvania.
		Hoffman coal group*	In South Somerset County, Pennsylvania.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Clarksburg fire clay	(2 - 3) Semi-plastic, cream to buff, clay - shale.
		Little Clarksburg limestone	(2 - 6) Hard, gray, lenticular, frequently shaly, develops a nodular appearance on weathering. Weathered section with Clarksburg clay appears as weathered red clay.
		Upper Clarysville coal*	In South Somerset County, Pennsylvania.
		Upper Clarksburg limestone*	In South Somerset County, Pennsylvania.
		Niverton shale*	In South Somerset County, Pennsylvania.
		Lower Clarysville coal*	In South Somerset County, Pennsylvania.
		Lower Clarksburg limestone*	In South Somerset County, Pennsylvania.
		Upper Clarksburg shale	(15 - 30) Hard, sandy, fissile, reddish to brown, sometimes with limestone nodules.
		Lower Connellsville sandstone (Hoffman of Maryland)	(10 - 35) Greenish-gray to brown, nearly always massive, sometimes pebbly, frequently micaceous. A good marker bed, recognized as a cliff former, about 200' below the Pittsburgh coal. Lenticular in Marion-Monongalia-Taylor Counties, West Virginia.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Normantown coal (Upper Hoffman of Maryland)	(0-1) Frequently represented by a dark gray to black carbonaceous shale, only locally a coal.
		Shale*	(23) Dark, sandy, Maryland.
		Middle Hoffman coal*	(2) Double-bedded, Maryland.
		Shale*	(8) Gray, limy, Maryland.
		Hoffman limestone*	(2) Dark, Siliceous, carbonaceous with fossils, Maryland.
		Lower Clarksburg shale	(15-30) Very similar to the Upper Clarksburg shales in the upper horizon and grading downward to a gray sandy shale.
		Lonaconing coal and shale and sandstone*	(0-20) In Pittsburgh Quadrangle, Pennsylvanoa. Probably equals horizons of Lower Hoffman coal, Clarysville sandstone, Upper and Lower Clarysville coals of Maryland.
		Morgantown sandstone (First Dunkard sandstone of Greene County, Pennsylvania)	(10-40) Greenish-gray on fresh surfaces, weathering to brown, massive, micaceous, sometimes with quartz pebbles. A cliff former along its outcrop, may be flaggy. In Pittsburgh Quadrangle, Pennsylvania may merge with Connellsville above and Birmingham below. It occurs as cross-bedded, medium to fine-grained with interbedded shale more massive at the bottom.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Wellersburg coal*	(0 - 14") in Maryland, and Somerset County, Pennsylvania, Donegal Quadrangle, Pennsylvania, Pittsburgh Quadrangle, Pennsylvania, South Somerset County, Pennsylvania.
		Wellersburg clay*	(5 - 15) Olive gray, weathers to red. In Maryland and Somerset County, Pennsylvania, Donegal Quadrangle, Pennsylvania, Pittsburgh Quadrangle, Pennsylvania, South Somerset County, Pennsylvania.
		Wellersburg limestone*	(0 - few inches) Occasionally present as nodular zone near Middle Wellersburg clay or may grade into shale in South Somerset County, Pennsylvania, in Maryland, Donegal Quadrangle, Pennsylvania, Pittsburgh Quadrangle, Pennsylvania, South Somerset County, Pennsylvania.
		Shale	(5 - 10) Generally gray, sandy, fissile, sometimes variegated.
		Orlando limestone (Elk Lick limestone in Marion-Monongalia- and Taylor Counties, West Virginia)	(0 - 4) Fresh water, dark, shaly, lenticular, often nodular.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Barton sandstone*	(0 - 20) In Tucker County, West Virginia.
		Elk Lick coal (Barton) (Four Foot of Maryland)	(2 - 4) Hard, good quality, approximately 265' below the Pittsburgh coal, one of the commercial coals of the basin.
		Shales and clay	(3 - 15) Ranges from a fire clay to a sandy, fissile shale.
		Elk Lick limestone (Possibly Barton limestone in Fayette County, Pennsylvania)	(2 - 10) Hard, gray, fresh water, lenticular and shaly.
		West Milford coal	(0 - 1) Not persistent, often represented by black, carbonaceous shale.
		Barton limestone*	(0 - 20) In South Somerset County, Pennsylvania.
		Birmingham shale and sandstone	(0 - 60) Generally 0 - 15 thick, red, sandy, often variegated. Frequently grades into the underlying Grafton sandstone. In Pittsburgh Quadrangle, Pennsylvania, may contain sandstone that may merge with Morgantown sandstone. Usually red, sometimes brown, lower part sandy shale or shaly sandstone up to 60' thick.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Washington red shale*	(?) In Fayette County, Pennsylvania.
		Duquesne coal*	(0 - 1) Irregular, often represented by carbonaceous or gray shale. In Pittsburgh Quadrangle, Pennsylvania.
		Duquesne clay*	(9 - 16) Olive-gray, frequently with limy nodules at base. In Pittsburgh Quadrangle, Pennsylvania.
		Duquesne limestone*	(0 - 3) Usually thin, fossiliferous, fresh water. In Pittsburgh Quadrangle, Pennsylvania.
		Grafton sandstone (Upper and Lower)	(20 - 30) Usually hard, massive, brown, often with quartz pebbles, occasionally shaly and soft. Can be mistaken for the Saltsburg sandstone which is 100' lower but is the first persistent sandstone found below the Elk Lick coal. In Pittsburgh Quadrangle, 0 - 8' thick and frequently represented by sandy shale. Upper and lower parts with intervening shales, limestones and coal in South Somerset County, Pennsylvania.
		Federal Hill Rider coal*	In South Somerset County between Upper and Lower Grafton sandstone.
		Federal Hill coal*	

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Glenshaw	Ames limestone and shales (Upper and Lower limestones with shale between and at bottom in Marion, Monongalia, Taylor Counties, West Virginia)	(5 - 20) Generally greenish-gray, limy, with marine fossils. A nodular limestone horizon is occasionally found at the top and bottom of the shale. A persistent formation and a good stratigraphic marker. In Pittsburgh Quadrangle, Pennsylvania, two or three closely spaced beds separated by few inches of limy shale totaling 0 - 4'. In South Somerset County, Pennsylvania, it includes an Ames coal.
		Ames coal*	
		Lavansville limestone*	(Lenticular grading into shale in South Somerset County, Pa.
		Harlem coal	(1 - 2) Generally clean, free of partings but not of commercial quality. A persistent bed just under the Ames shale and limestone in West Virginia. In Pittsburgh Quadrangle, Pennsylvania, usually only a few inches thick.
		Fire clay and shale*	

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Pittsburgh Red Beds	(40 - 75) Consists of two portions separated by the Jane Lew sandstone. The portion between the Jane Lew sandstone and the Harlem coal is yellowish near the top and grades downward to a red, sandy or variegated shale. Frequently the yellow and red shales are separated by Ewing limestone which are less common in the Pittsburgh Quadrangle, Pennsylvania. The lower portion below the Jane Lew sandstone is generally a red shale that has good brick making possibilities.
		Ewing limestone*	(5) Hard, gray. See above.
		Jane Lew sandstone	(10 -25) See above, generally not present, it grades from a shaly, flaggy to a hard, massive sandstone that may form cliffs, greenish. See below.
		Saltsburg sandstone	(15 - 60) Nearly always massive, hard and coarse, frequently conglomeratic, sometimes gray on fresh fractures but more often mottled with iron oxide giving it a brown appearance. In Pittsburgh, Pa. Quadrangle, Pa., usually in 2 or 3

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Saltsburg sandstone (Cont'd)	parts, one 15-20 feet thick just below Pittsburgh red beds as a shaly sandstone, shale or clay equivalent to Jane Lew; a second section between Bakerstown coal and the Woods Run horizon usually only a few feet thick but occasionally massive coarse grained and about 5' thick; a third between Woods Run horizon and Pine Creek limestone usually more persistent than upper two beds and massive, cross-bedded but occasionally represented by shale. In South Somerset County, Pennsylvania it is lenticular sometimes cutting out the Upper Bakerstown coal.
		Upper Bakerstown coal*	(2 - 3) In Pittsburgh Quadrangle, Pennsylvania.
		Cambridge red shale*	(0 - 12) In Pittsburgh Quadrangle, Pennsylvania.
		Woods Run limestone*	(6 - 12) In Pittsburgh Quadrangle, Pennsylvania. Usually thin, impure, fossiliferous, ferruginous, argillaceous, limy beds with 6" Upper Bakerstown coal.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Friendsville shale*	(20 - 30) In South Somerset County, Pennsylvania and probably equivalent to Woods Run, Cambridge reds.
		Bakerstown (Thomas) coal	(1 - 3) Persistent, often of commercial quality, generally free of shale partings, usually separated from the Saltsburg sandstone by a few feet of carbonaceous shale, extensively mined in northern West Virginia but only a few inches thick in Pittsburgh Quadrangle, Pennsylvania.
		Thomas fire clay and shale*	(5) In South Somerset County, Pennsylvania the Thomas clay grades into the Albright limestone.
		Albright limestone*	In Tucker County, West Virginia. See above.
		Shales	(30 - 40) A series of fissile, gray to variegated shales.
		Pine Creek limestone (Cambridge limestone of Maryland and possibly Fayette County, Pa. and South Somerset County, Pa.)	(0 - 2) Occasionally found as a thin hard lenticular to nodular horizon 30 to 40' below the Bakerstown coal. No marine fossils. In Pittsburgh Quadrangle, Pa., gray brittle, sometimes with fossils and mica flakes which weather to red color, sometimes merges into massive

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Pine Creek limestone (Cont'd)	sandstone. Usually underlain by clay but also by sandy shale and sandstone.
		Meyersdale shales	(70 - 80) Generally dark, fissile, sandy.
		Buffalo sandstone	(20 - 50) Gray, massive, frequently with quartz pebbles, readily recognized as a cliff former, a good marker bed, approximately 100' below the Bakerstown coal in West Virginia. In Pittsburgh Quadrangle, Pennsylvania it is cross-bedded, massive gray but occasionally thin-bedded.
		Brush Creek limestone and shale	(10 - 15) The shale is dark and fissile, marine fossils. The limestone when present is a dark, carbonaceous lenticular deposit seldom more than several inches thick at the top. In Pittsburgh Quadrangle, Pennsylvania the limestone is frequently absent and only the shale is present.
		Brush Creek coal	(1 - 3) Not consistent, often represented by a black carbonaceous shale, frequently split by one or more shale partings.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Brush Creek fire clay and shale*	(5 - 15) Grades from a fire clay to a hard, fissile shale with
		(Irondale limestone)*	ferriferous limestone layers called the Irondale limestone in South Somerset County, Pennsylvania where the Brush Creek clay grades into the Irondale limestone.
		Corinth sandstone*	In South Somerset County, Pennsylvania, lenticular.
		Humbert coal*	In South Somerset County, Pennsylvania grades into Mahoning red beds.
		Upper Mahoning sandstones (Upper and Lower)	(30) Massive, grayish and hard, frequently contains quartz pebbles. A ridge or bluff former, it sometimes is split near the center with a thin coal (Mahoning) and a plastic fire clay (Thornton). In Pittsburgh Quadrangle, Pa. it is medium-grained, gray, arkosic with small mica flakes. Occurs up to 20' thick between Brush Creek and Mahoning coals, frequently occurs between the Mahoning and Freeport coals and known to cut out the Freeport coal and rest upon deeper strata.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Conemaugh	Mahoning limestone* and clay	(0 - 4 inches).
		Mahoning coal*	(0 - 2) Usually thin with an Upper, Middle and Lower portion in Pittsburgh Quadrangle, Pennsylvania and South Somerset County, Pennsylvania.
		Thornton fire clay*	(0 - 5)
		Lower Mahoning sandstone*	(45)
		Piedmont coal*	(0 - 0.5) In Pittsburgh Quadrangle, Pennsylvania.
		Upper Freeport Rider coal*	(0 - 1) In Pittsburgh Quadrangle, Pennsylvania and South Somerset County, Pennsylvania.
		Uffington shale	(0 - 10) Dark gray, siliceous, with plant fragments, frequently quite shaly. Roof material for the Upper Freeport coal.

* Variations from the generalized section in the Barbour-Upshur, Western Randolph Counties, West Virginia report by the West Virginia Geological Survey.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Allegheny	Freeport	
		Upper Freeport coal (Davis)	(2 - 6) Ranges from soft to medium hard with one to two shale partings.
		Bolivar fire clay	(2 - 5) Plastic when wet, silty feel when dry, light in color.
		Upper Freeport limestone*	(1) In Lewis-Gilmer Counties, West Virginia also Marion-Monongalia-Taylor Counties, West Virginia, Tucker County, West Virginia, Preston County, West Virginia. Donegal Quadrangle, Pennsylvania.
		Upper Freeport sandstone (Butler sandstone in Donegal Quadrangle, Pa.)*	(70 plus or minus) Massive, cliff-forming, grayish, coarse, hard and contains abundant mica.
		Middle Freeport coal*	Sometimes contained in Upper Freeport sandstone in Preston County, West Virginia.
		Lower Freeport coal	(0 - 2) Frequently represented by a hard, black shale.
		Shale and fire clay	(2 - 6) Dark shale, sometimes with nodules of fresh water limestone.
		Lower Freeport limestone*	(5) In Marion-Monongalia-Taylor Counties, West Virginia, Tucker County West Virginia, Preston County, West Virginia, Donegal Quadrangle, Pennsylvania.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Allegheny	Lower Freeport sandstone (Upper division only in Lewis-Gilmer Counties, West Virginia, Preston County, West Virginia, Freeport sandstone of Donegal Quadrangle, Pennsylvania)	(30) Massive, gray on fresh fractures and buff on weathered faces, contains a pebble conglomerate near its base. Can be used as a marker bed.
		Upper Kittanning coal (Montell of Maryland)	(1 - 4) Frequently has one or two shale partings, soft and quite bony in places. Generally has the Lower Freeport sandstone as a roof, but locally a thin 3 - 8' fissile shale is present.
		Shale and fire clay	(3 - 10) Dark, sandy, clay shale. Occupies the position of the Upper Kittanning fire clay, Johnstown limestone and Hardman fire clay of Marion-Monongalia-Taylor Counties, West Virginia, Preston County, West Virginia and the limestone in Tucker County, West Virginia, Donegal Quadrangle, Pennsylvania.
		Johnstown limestone*	See above

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Allegheny	Upper East Lynn sandstone (Lowest Freeport sandstone in Lewis-Gilmer Counties, Marion-Monongalia-Taylor Counties, West Virginia. Probably equals the Upper Worthington sandstone of Donegal Quadrangle, Pa. and Upper Westernport sandstone of Fayette County, Pennsylvania)	(30 - 50) Massive, grayish on fresh fractures becoming buff colored soon after exposure, iron-stained, generally fine-grained, hard and has thin soft shaly zones. Below the Middle Kittanning coal in Tucker County, West Virginia. Lower Freeport lower division rests on the Middle Kittanning coal in Preston County, West Virginia.
		Shale (Miners Draw slate)	(5 - 20) Hard, fissile, very splintery and broken, often has a pyrite-bearing zone near its base, locally the basal portion is a gray slicken-sided clay shale. Sometimes absent in the section.
		Middle Kittanning coal	(2 - 5) Soft, columnar, generally with two to three shale partings.
		East Lynn horizon (Probably equal to Lower Worthington sandstone of Donegal Quad., Pennsylvania and Lower Westernport sandstone of Fayette County, Pennsylvania)	(1 - 30) Varies from a hard, fissile, sandy, gray shale to a very hard, gray to black sandstone. Very lenticular, frequently so thin that the Middle and Lower Kittanning coals are mined as one seam. Lower Kittanning Rider Coal occasionally appears in Westmoreland County, Pennsylvania.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Allegheny	Lower Kittanning coal	(3 - 8) Columnar coal with two to three shale and bone partings.
		Shale and fire clay	(10 - 30) - Gray, fissile, sandy sometimes clay, frequently contains numerous pyrite at top, locally contains sandstone lenses.
		Lower Kittanning sandstone*	(10- 20) Massive cutting into the underlying strata and Clarion coal in places.
		Vanport limestone*	(2) Ferriferous in Lewis-Gilmer Counties, West Virginia, also Marion-Monongalia-Taylor Counties, West Virginia, Preston County, West Virginia, Donegal Quadrangle, Pennsylvania.
		Clarion sandstone*	(20) In Lewis-Gilmer Counties, West Virginia
		Clarion coal	(0 - 2) Multiple-bedded, usually contains large amounts of shale.
		Clarion (Mt. Savage) clay and shale*	(10)
		Brookville coal*	(1) Seldom found
		Brookville clay*	Donegal Quadrangle, Pennsylvania.

* Variations from the generalized section in the Barbour-Upshur, Western Randolph Counties, West Virginia report by the West Virginia Geological Survey.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Pottsville	Kanawha Group 350 - 675'	
		Homewood sandstone	(25 - 60) Grayish white, massive or current-bedded, often pebbly; in Fayette County, Pennsylvania commonly comprised of 5 - 30' of clean, massive white upper bed and a lower 20 - 50' of multiple and cross-bedded layers.
		Tionesta coal*	(1) In Marion-Monongalia-Taylor Counties, West Virginia.
		Mt. Savage fire clay*	(5) In Marion-Monongalia-Taylor Counties, West Virginia.
		Fire clay and shale with coal streaks*	(30) In Marion-Monongalia-Taylor Counties, West Virginia.
		Hammond fire clay	(5 - 15) May be represented by sandy shales (Tionesta coal and Mt. Savage fire clay appear to be absent by disconformity in Randolph County, West Virginia. Iron carbonate nodules common in Fayette County, Pennsylvania. In South Somerset County, Pennsylvania, the overlying gray and dark gray shale becomes sandy upwards but in places the Homewood sandstone lies directly on the Mercer coal.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Pottsville	Upper Mercer coal	(0 - 5) Multiple-bedded, lenticular. Three distinct beds in Fayette County, Pennsylvania with the Homewood sandstone observed to cut into the Mercer coal.
		Shales (Kanawha black flint)	(5 - 21) Dark, sandy, Kanawha black flint. In South Somerset County, Pennsylvania. Beneath the coal there is a siliceous clay zone that grades downward into silt and sandstone.
		Lower Mercer (Stockton) coal	(0 - 5) Often hard and splinty.
		Fire clay and shale*	(8) Appears in Lewis-Gilmer Counties, West Virginia and in Fayette County, Pennsylvania. Also contains iron carbonate nodules.
		Upper Connoquenessing sandstone (Upper Coalburg sandstone)	(50 - 100) Gray, massive, pebbly. (A portion possibly correlative with the Upper Coalburg sandstone). Can be mistaken for Homewood sandstone when present alone. May be clay shale or sandy shale in Fayette County, Pennsylvania. May merge with Homewood sandstone in South Somerset County, Pennsylvania.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Pottsville	Kanawha Group (cont.)	
		Quakertown "Rider" coal (Coalburg?)	(0 - 1) Lenticular.
		Quakertown (Lower Coalburg) shale	(0 - 11) Black, fissile, often with fossils.
		Quakertown (Winifrede) coal	(0 - 3) Lenticular.
		Clay shale*	(0 - 3) Sometimes present.
		Lower Connoquenessing (Lower Winifrede) sandstone	(20 - 35) Gray, massive, mica along bedding planes. Represented by sandy shale in part in Fayette County, Pennsylvania. Poorly developed in South Somerset County, Pennsylvania.
		Shale	(5 - 20) Sandy, probably represents Winifrede limestone.
		(Winifrede limestone)*	(5 - 10) Fissile shales with fossils in Tucker County, West Virginia. See above.
		Upper Chilton sandstone	(15 - 30) Gray, massive.
		Shale (Cleveland shale Williamson coal)	(5 - 8) Sandy, dark and sandy with Williamson coal (?) streaks in Tucker County, West Virginia. Possibly Cleveland shale in Lewis-Gilmer Counties.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Pottsville	Kanawha Group (Cont.)	
		Chilton coal	(0 - 2) Seldom found.
		Shale (Blackwater Dingess)	(5 - 8) Sandy, probably includes (Blackwater Dingess). Shale and limestone horizon of dark fissile shales and ferruginous limestone of Tucker County, West Virginia.
		Upper Cedar Grove sandstone	(20 - 25) Gray, massive.
		Cedar Grove coal	(0 - 2)
		Shale	(5 - 10) Sandy.
		Peerless sandstone	(10 - 48) Gray, massive, correlative with Lower Cedar Grove sandstones of some reports.
		Alma coal	(0 - 2) Medium-hard.
		Shale	(0 - 5) Sandy.
		Monitor sandstone	(0 - 22) Gray, massive, same as Logan Sandstone of Logan-Mingo Counties, West Virginia.
		Campbell Creek (Peerless Bench) coal	(1 - 3) Medium hard, usually single-bedded.
		Shale	(10 - 20) Sandy.
		Brownstown sandstone	(10 - 47) Gray, massive.
		Powellton coal	(1 - 3) Medium-hard, single-bedded.
		Shale	(0 - 10) Sandy.
		Eagle sandstone	(20 - 46) Gray, massive.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Pottsville	Kanawha Group (cont.)	
		Newlon limestone and shale	(0 - 20) Black, fissile with limestone concretions.
		Eagle coal (Gimmel seam)	(1 - 4) Medium-hard with bony streaks.
		Decota sandstone	(10 - 20) Gray, massive.
		Shales	(5 - 10) Dark, sandy.
		Little Eagle coal	(0 - 1) Seldom found.
		Grapevine sandstone	(0 - 20) Gray, massive.
		Eagle shale	(2 - 10) Dark with marine fossils in southern West Virginia.
		Lower War Eagle coal	(0 - 1) Seldom found.
		Lower Gilbert sandstone	(25 - 50) Gray, massive.
		Gilbert shale*	(5 - 8) Dark laminated and appearing in Tucker County, W. Va.
		Gilbert coal	(1 - 5) medium-soft.
		Shale	(3 - 5) Sandy.
		Dotson sandstone	(10 - 30) Gray, massive, often absent by disconformity.
		Douglas coal	(0 - 1) Soft, lenticular.
		Lower Dotson sandstone	(0 - 10) Usually absent or represented by sandy shale.
		Douglas shale	(3 - 5) Dark, sandy, laminated. Often absent by disconformity.
		Lower Douglas coal	(0 - 2) Soft.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Pottsville	Kanawha Group (cont.)	
		Shale	(0 - 5) Gray, sandy.
		New River Group	200 - 400'
		Upper Nuttall sandstone	(10 - 30) Gray, massive, sometimes pebbly. Frequently combined with Lower Nuttall.
		Shale	(0 - 10) Dark, sandy.
		Iaeger "B" coal	(0 - 1) Seldom found.
		Lower Nuttall sandstone	(20 - 50) Gray, massive, sometimes pebbly, frequently combined with Upper Nuttall.
		Upper Iaeger shale	(2 - 5) Dark, sandy.
		Hughes Ferry coal	(1 - 3) Single-bedded, soft, columnar.
		Shale	(5 - 10) Sandy.
		Middle Iaeger sandstone	(10 - 23) Gray, massive.
		Lower Iaeger coal	(1 - 2) Soft.
		Lower Iaeger shale	(0 - 5) Sandy.
		Harvey sandstone	(15 - 37) Gray or brown, massive.
		Sandy Huff shale	(0 - 5) Dark gray, argillaceous, laminated.
		Castle coal	(1 - 3) Soft, columnar, single or double-bedded.
		Shale	(0 - 10) Sandy.
		Guyandot sandstone	(20 - 38) Grayish-white, massive.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Pottsville	New River (cont'd)	
		Skelt shale	(0 - 5) Dark gray with marine fossils.
		Sewell "B" coal	(0 - 2) Soft, columnar.
		Shale	(0 - 10) Sandy.
		Sewell "A" coal	(0 - 1) Usually absent.
		Lower Guyandot sandstone	(10 - 20) Grayish-white, massive, coarse. Sometimes combined with Guyandot sandstone.
		Hartridge shale	(2 - 5) Black, fissile, carbonaceous with iron nodules, with fossils.
		Sewell (Sharon of Pennsylvania coal)	(2 - 5) Soft, columnar, usually single-bedded.
		Shale	(5 - 10) Sandy.
		Welch sandstone	(10 - 27) Gray, massive or shaly.
		Shale	(0 - 5) Dark argillaceous lenticular with fossils.
		Welch coal	(1 - 3) Soft, columnar.
		Shale	(3 - 15) Sandy.
		Upper Raleigh (Sharon) sandstone	(25 - 60) Grayish-white, massive pebbly (usually the base of the Pottsville west of Tygart Valley).
		Little Raleigh coal	(0 - 1) Soft, seldom found
		Little Raleigh sandstone	(15) Sandy shale and shaly sandstone.

Age	Rock Unit	Formation	Thickness in feet and description
Pennsylvanian	Pottsville	New River (cont.)	
		Beckley coal	(0 - 1) Occasionally present but slaty.
		Sandstone	(0 - 15) Shaly or sandy shale. Horizon of the Quinnimont sandstone and Quinnimont shale.
		Fire Creek (Quinnimont) coal	(0 - 5) Soft, double-bedded.
		Shale	(0 - 10) Sandy with sandstone.
		Little Fire Creek coal	(0 - 1) Lenticular, seldom found.
		Pineville sandstone*	(0 - 20) Lenticular.
Mississippian	Mauch Chunk		Red and green shales, lenticular, micaceous, flaggy sandstones; massive sandstones at the bottom.
	Greenbrier		Siliceous limestone at top, interbedded with red and gray limy shales; massive limestone at bottom.
	Pocono		Gray and brown sandstone with intervening gray, sandy shales, sometimes ferruginous and occasional coal streaks; Big Injun conglomerate at top.

Age	Rock Unit	Formation	Thickness in feet and description
Devonian	Catskill		Alternating beds of red shale and red and brown fine-grained micaceous sandstone.

*Variations from the generalized section in Randolph County, West Virginia report by the West Virginia Geological Survey.